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MANUAL OF NAVIGATION

NAPIER

MANUAL OF NAVIGATION.

MANUAL

OF

NAVIGATION.

BY

ROBERT ASSHETON NAPIER, LIEUT. R.N.R.,

MEMBER OF THE INSTITUTION OF NAVAL ARCHITECTS.

SECOND EDITION.

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PREFACE.

THE Author has been induced to publish this Manual owing to the inconvenience he has at different times experienced from the want of a book containing all the rules and examples required for daily use at sea.

The principal object kept in view has, therefore, been to furnish a compact book of reference for all calculations necessary for the efficient discharge of navigating duties, and while there is nothing included in its pages but what will be of use to the careful seaman, it is hoped that nothing has been omitted which might advantageously have been inserted.

The conclusions to be derived from a careful study of the ever-varying signs of the weather have been placed before the reader as clearly and consecutively as possible.

Considerable care has been taken to produce in a concise form rules for finding and applying the Deviation of the compass. Attention is also directed to the practice of reducing the soundings found by the lead in thick weather, at night, or at any time when standing into shoal water, to the mean height of low water at ordinary spring tides, for exact comparison with the depths marked on the chart. Ignorance or neglect of this simple correction too frequently causes a disastrous termination to a hitherto successful voyage.

All that has been undertaken in connection with observations of celestial objects are a few detailed calculations under various conditions, for purposes of easy reference. Obsolete and approximate methods, which tend to retard rather than advance the science of navigation, have been avoided as far as possible.

The Lunar problem for ascertaining Greenwich time, and hence the longitude, is beyond the scope of this manual, and Sumner's method of equal altitudes, used in conjunction with

Azimuth Tables, has been substituted. To a man whose brain is confused by long watching and the anxiety of running into dangerous waters, the increased facility afforded by this method must obviously be of the greatest benefit, and will go far to recommend its general adoption.

Lunars are not so often worked in steamers as formerly, owing to the rapidity with which passages are made from land to land, and the opportunities thereby afforded of ascertaining the error of the chronometer. They are never likely to be entirely superseded in sailing vessels, as chronometers, although compensated, are more or less liable to variation and error, when exposed to sudden changes of temperature and the continued damp of long voyages, such as to the East Indies or China Seas. Although frequently practised, Lunars are not to be absolutely depended upon to within ten or fifteen miles, as an error of only twenty seconds in the Lunar distance will give a corresponding error of about ten minutes of longitude.

As books of some sort are almost indispensable, a list of the best modern works on various analogous subjects is appended for the further study of the reader.

R. A. N.

GLASGOW, October, 1877.

PREFACE TO THE SECOND EDITION.

THE present edition of this Manual is almost a reprint of that published in 1877, with the exception of sundry additions and re-arrangements to date, and a few pages on the development of the Law of Storms.

R. A. N.

GLASGOW, August, 1880.

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MANUAL OF NAVIGATION.

SEAMEN'S PROVERBS.

A rainbow in the morning
Is the sailor's warning,
A rainbow at night
Is the sailor's delight.

The evening red and morning grey
Are sure signs of a fine day,
But the evening grey and morning red
Make the sailor shake his head.

With the rain before the wind
Your topsail halyards you must mind,
But when the wind's before the rain
You may hoist your topsails up again.

If clouds are gathering thick and fast
Look out sharp for sail and mast,
But if they lag upon their road
Keep your flying kites abroad.

Mackerel sky and mare's tails
Make lofty ships carry low sails.
When the wind shifts against the sun,
Trust it not, for back it will run.

When the glass falls low prepare for a blow,
When it has risen high let all your kites fly.

First rise after very low indicates a stronger blow.
Long foretold, long last; short notice, soon past.

WEATHER SIGNS.

Whether clear or cloudy.—In the Evening.

A rosy sky foretells fine weather.
A dark, dull red sky foretells rain.
A bright yellow sky foretells wind.
A pale yellow sky foretells rain.
A tawny or coppery sky foretells wind.
A sickly greenish sky foretells wind and rain.

Whether clear or cloudy.—In the Morning.

A grey sky foretells fine weather.
A red sky foretells much wind and perhaps rain.
A dark, gloomy blue sky foretells wind.
A light, bright blue sky foretells fine weather.

Thus, by the preponderance of red, yellow, green, grey, or other tints, the coming weather may be foretold with considerable accuracy.

A high dawn (that is, when the first indications of daylight are seen above a bank of clouds) foretells wind.

A low dawn (that is, when the first indications of daylight are seen very low on the horizon) foretells fine weather.

Soft delicate-looking clouds foretell fine weather.

Hard-edged oily-looking clouds foretell wind.

Generally, the softer the clouds appear, the less wind (but perhaps more rain) may be expected; and the harder, more greasy, rolled, tufted or ragged they appear, the stronger the coming wind will prove.

Light, delicate, quiet tints or colours, with soft, undefined forms of clouds, indicate and accompany fine weather; but gaudy or unusual hues, with hard, definitely-outlined clouds, foretell rain and probably strong wind.

High upper clouds crossing the sun, moon, or stars, in a direction different from that of the lower clouds, or of the wind then blowing below, foretell a change of wind toward their direction, except between the Tropics or in the regions of the Trade Winds, where there is generally an upper and counter current of air, with very light clouds, which is not an indication of any approaching change.

Dew is an indication of fine weather, its formation never begins under an overcast sky, or when there is much wind.

Remarkable clearness of the atmosphere near the horizon; distant objects, such as hills, unusually visible or well defined; and what is called "a good hearing day," may be mentioned among signs of rain, if not wind.

More than usual twinkling of the stars, indistinctness or apparent multiplication of the moon's horns, haloes, "wind-dogs, "and the rainbow, are more or less significant of increasing wind, if not approaching rain, with or without wind.

The "young moon with the old moon in her arms" is a sign of bad weather in the temperate zones.

Much refraction is a sign of easterly wind.

After very warm and calm weather a storm is likely to follow; or at any time when the atmosphere is heated much above the average temperature.

When sea birds fly out early and far to seaward, moderate wind and fair weather may be expected.

An officer of a watch, with a good eye for clouds and signs of changing weather, may save his men a great deal of unnecessary exposure, as well as work, besides economising sails, spars, and rigging, to an extent often too little appreciated.

WEATHER GLASSES.

The Barometer shows the pressure of the atmosphere.

The Thermometer shows the temperature of the atmosphere.

The Hygrometer shows the dampness of the atmosphere.

In South Latitude read South for North.

The Barometer RISES, for northerly wind (including from north-west by the north, to the eastward), for dry or less wet weather,—for less wind,—or for more than one of these changes; except on a few occasions when rain, hail, or snow comes from the northward with strong wind.

The Barometer FALLS, for southerly wind (including from south-east by the south, to the westward), for wet weather,—for stronger wind,—or for more than one of these changes; except on a few occasions when moderate wind with rain or snow comes from the northward.

A Thermometer FALLS, for change of wind toward northerly directions.

A Thermometer RISES, for change of wind toward southerly directions.

Moisture or dampness in the atmosphere, as shown by the Hygrometer, increases before rain, fog or dew.

The air of the Polar or Northerly current has been chilled, and is heavy, cold and dry; therefore while it is blowing, the Barometer is high and the weather usually dry.

The air of the Equatorial or Southerly current has been heated, and is light, warm, and moist; therefore while it is blowing, the Barometer is low and the weather usually wet.

Electricity in the atmosphere, thunder or lightning, do not affect the Aneroid or a Mercurial Barometer.

DESCRIPTION OF THE BAROMETER.

The Barometer consists of a straight glass tube about 34 inches in length, closed at one end, and filled with pure mercury; it is placed upright, with the open end down, in a small cup or cistern partially filled with mercury exposed to atmospheric pressure.

The mercury in the tube sinks, thereby causing a vacuum to be formed in the upper part of the tube, until the top of the column stands at an average height of nearly 30 inches above the surface of the mercury in the cistern.

The pressure which the column of mercury exerts at its base is quite independent of the diameter or capacity of the tube, but depends entirely on the height of the column, which rises or falls as the atmosphere becomes heavier or lighter and presses with more or less weight on the mercury in the cistern.

When the Barometer is at the sea level, the weight or pressure of the atmosphere is about 15 pounds on a square inch of surface; but a cubic inch of mercury weighs about half a pound, therefore, assuming the sectional area of the tube to be equal to a square inch, a column 30 inches in height will contain 30 cubic inches of mercury and exert a pressure at its base equal to a weight of 15 pounds, so that the column of mercury in the tube is held in equilibrium by the pressure of the atmosphere on the mercury in the cistern; hence the susceptibility of the instrument, and its power to indicate the slightest change in the condition of the atmosphere.

The column FALLS fully a tenth of an inch for every 100 feet of elevation above the sea level, and RISES fully a tenth of an inch for every 100 feet of depression below the sea level, because there is a less head or weight of air above it in the one case and a greater in the other.

The layers of atmosphere extend to about 50 miles from the surface of the Earth.

Mercury is 13·596 times heavier than pure fresh water, and 13·251 times heavier than ordinary sea water.

DESCRIPTION OF THE BAROMETER DIAGRAM.

The Barometer Diagram is one of the most useful records that can be kept at sea. It is ruled vertically with heavy lines for every day at noon, and light lines for every four hours ; it is also ruled horizontally, with heavy lines for every inch and half-inch, and light lines for every twentieth of an inch : thus, each space represents one-twentieth of an inch of the barometric scale taken horizontally, and four hours taken vertically.

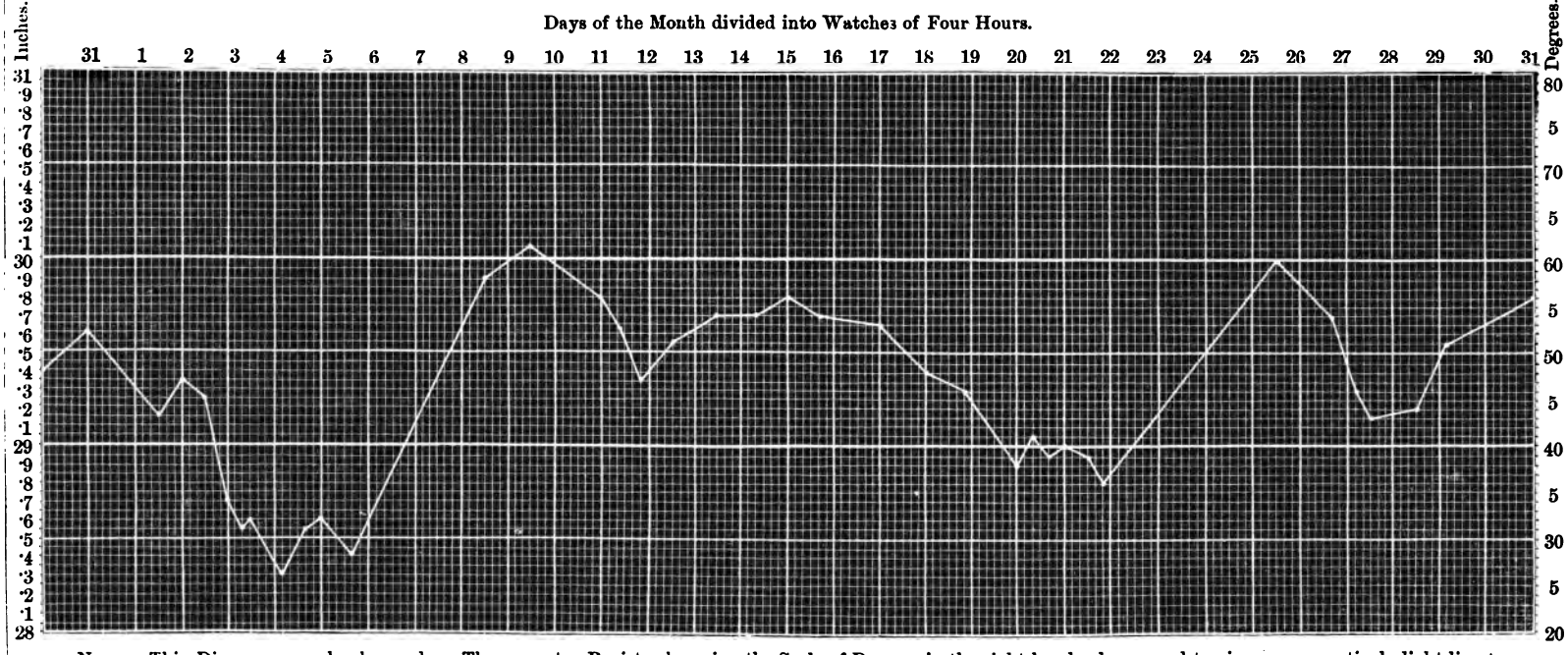
In this form the daily movements of the mercurial column should be recorded by a dot at the place corresponding to its height and the time of each observation. These dots being joined together, result in an irregular line, which shows at a glance what has been the range of the column during the immediately preceding days, by which, and not merely by the last observation, a judgment may be formed of the weather to be expected. If closely attended to, this diagram will prove to be of considerable utility, and will in some degree reward the trouble of keeping an accurate and regular record.

For practical purposes, the diagram should be ruled to the scale of one-tenth of an inch to every four hours, for a month of 31 days, and one-tenth of an inch to every twentieth of an inch of the barometric scale from 28 to 31 inches inclusive; thus, after allowing space for the last day of the preceding month, and end columns for figures of side scale, the dimensions of the diagram ought to be about 20 inches long by 6 inches deep.

BAROMETER DIAGRAM.

Place,.....*Month,*.....*Year,*.....

Days of the Month divided into Watches of Four Hours.



NOTE.—This Diagram can also be made a Thermometer Register by using the Scale of Degrees in the right hand column, and tracing a comparatively light line to represent the range of temperature.

INDICATIONS OF THE BAROMETER.

In the Temperate Zones at the sea level, the column of mercury ranges from about 28 to 31 inches, while in the British Islands the average height is about 29·9 inches. If the mercury RISES steadily above its mean height, while the weather gets colder and the air becomes drier; north-westerly, northerly, north-easterly winds, or less wind, less rain, or snow, may generally be expected. If, on the contrary, the mercury FALLS, while the weather gets warmer and the air becomes damper; wind and rain may be looked for from the south-east, south, or south-west.

If the weather gets warmer while the mercury is high and the wind north-easterly, a shift of wind to the south may be looked for. If, on the other hand, the weather becomes colder while the wind is south-westerly and the mercury low, a sudden squall or perhaps a storm from the north-west, with a fall of snow if it be winter time, may be looked for.

The wind usually shifts with the sun, viz., from left to right in the northern hemisphere—a change in this direction is called VEERING. (In the southern hemisphere motion with the sun is, of course, from right to left.) Thus an east wind shifts to west through south-east, south, and south-west, and a west wind shifts to east through north-west, north, and north-east. If the wind shifts the opposite way, viz., from west to south-west, south, and south-east, the change is called BACKING, and it seldom occurs unless when the weather is unsettled.

In WINTER, after a prevalence of easterly winds, if the barometer begins to fall, and the thermometer to rise, the sky being densely clouded, a gale which commences to blow from south-east will veer to south-west, while the barometer continues to fall. As soon as the wind passes the south-west point, the barometer begins to rise and the thermometer to fall suddenly; then a heavy

shower of rain falls, and a strong west-north-west or north-west wind may follow, with a clear sky.

If the wind backs from the north-west towards west and south-west, the bad weather is very likely to continue.

In WINTER, if the barometer suddenly rises very high and a thick fog sets in, it is a sure sign that the north-east and the south-west winds are fighting each other. Neither of them can make head against the other, and there is a calm; but there is great danger of a severe gale succeeding such a state of things.

The barometer begins to rise occasionally before the conclusion of a gale, sometimes even at its commencement, as the equilibrium of the atmosphere begins to be restored. Although the mercury falls lowest before high winds, it frequently sinks considerably before a heavy fall of rain or snow.

A fall of half a tenth (·05) or more in AN HOUR is a sure warning of a gale, which rises from the southward and veers to the westward as the mercury rises.

A sudden rise of the barometer is very nearly as bad a sign as a sudden fall, because it shows that the equilibrium of the atmosphere is unsteady.

Allowance should always be made for the state of the column during some days, as well as some hours previous, because it may be affected by remote causes as well as by changes in the immediate vicinity. As a general rule, the longer a change of wind or weather is foretold by the barometer, the longer will the presaged weather last; and conversely, the shorter the warning the less time will such weather continue. Sometimes severe weather from an equatorial direction, not lasting long, may cause no great fall of the mercury, because followed by a duration of wind from the polar regions; and at times the mercury may fall considerably with polar winds and fine weather, because a continuance of equatorial wind is about to follow.

The column of mercury in a good barometer usually

stands, on an average, some tenths of an inch higher with or before polar and easterly winds than it does with or before equatorial and westerly winds, of an equal strength and moisture, in all parts of the ocean. Thus, with a low but rising glass, finer weather is USUALLY expected, while instead of that, a strong wind perhaps accompanied by rain, hail, or snow, rises from the polar direction. Conversely, with a high but falling glass, wind or rain or both, are USUALLY expected, yet neither follow to any remarkable degree; only a change of wind from one quarter to another taking place. In the Tropics, at the sea level, a few tenths above or below 30 inches are seldom exceeded, except before Hurricanes, or in the Bay of Bengal during the respective Monsoons, when the mercury sometimes falls below 28 even to 27 inches. On some coasts the barometer is differently affected by the wind, as it may happen to blow from the sea or from the land, the mercury rising on the approach of the sea breeze, and falling previous to the setting in of the land breeze. The tides are so much affected by atmospheric pressure that a rise of one inch in the barometer (indicating an INCREASE of one-thirtieth part of the atmospheric pressure) will have a corresponding fall in the tides of about one foot. Conversely, a fall of one inch in the barometer (indicating a DIMINUTION of one-thirtieth part of the atmospheric pressure) will have a corresponding rise in the tides of about one foot.

Continued observations have proved the inter-tropical barometric tides, or diurnal rise and fall of the mercury. The column rises from about 4 a.m. till about 10 a.m., when it reaches its highest point; then falls till about 4 p.m., when it reaches its lowest point; it again rises till about 10 p.m., then again falls till about 4 a.m., and so on. If, in any inter-tropical region the mercury moves contrary to this rule, comparatively unfavourable weather may be expected. The rise and fall, or diurnal range, is

about six or seven hundredths of an inch, or a little less than a tenth. The regularity of the oscillations is disturbed by land.

DESCRIPTION OF THE ANEROID.

The Aneroid is an instrument which has come into extensive use, owing to its convenient size and portability. It is especially suited for use on board small vessels, in which there is not space to suspend a barometer; and, of course, all that is stated in this manual regarding the barometer as a weather indicator, applies to the aneroid, so far as a single observer is concerned.

In the aneroid, atmospherical pressure is measured by its effect in altering the shape of a small hermetically sealed circular metallic box with corrugated top, from which almost all the air has been exhausted, and which is kept from collapsing by a powerful spring.

When atmospherical pressure rises above the amount which was recorded when the instrument was made, the top is forced inwards, and *vice versâ* when pressure falls below that amount the top is forced outwards by the spring. These motions are transferred by a system of levers and springs to a hand which moves on the dial.

Aneroids are very sensitive, but unfortunately they do not preserve their accuracy completely. If a table of corrections be determined for any aneroid, it will be found that after a time the instrument will have undergone some change, and that the values of the corrections require alteration, so that comparison with a standard barometer is necessary. In every case of such comparison the readings of the mercurial barometer should be reduced to 32° Fahrenheit.

A serious objection to the scientific utility of these instruments is their liability to injury from rust, or to the alteration of force in the springs used in their construction.

BEAUFORT NOTATION.

(MODERNIZED.)

FIGURES TO DENOTE THE FORCE OF THE WIND.	
0 Calm,	No way.
1 Light Air,	Steerage way.
2 Light Breeze,	Clean full, about 2 knots.
3 Gentle Breeze,	Clean full, about 4 knots.
4 Moderate Breeze,	Clean full, about 6 knots.
5 Fresh Breeze,	With royals ("close hauled.")
6 Strong Breeze,	Topgallantsails over single reefs.
7 Moderate Gale,	Two reefs in topsails.
8 Fresh Gale,	Three reefs in topsails, or Lower topsails and courses.
9 Strong Gale,	Close reefed topsails, or Lower topsails and reefed courses.
10 Whole Gale,	Close reefed maintopsail, or Lower maintopsail and reefed foresail.
11 Storm,	Storm staysails or trysails.
12 Hurricane,	No canvas.

LETTERS TO DENOTE THE STATE OF THE WEATHER.	
B	Blue sky; whether with clear or hazy atmosphere.
C	Cloudy; *i.e.*, detached opening clouds.
D	Drizzling rain.
F	Fog.
G	Gloomy dark weather.
H	Hail.
L	Lightning.
M	Misty or Hazy, so as to interrupt the view.
O	Overcast; *i.e.*, the sky covered with one impervious cloud.
P	Passing showers.
Q	Squally.
R	Rain; *i.e.*, continuous rain.
S	Snow.
T	Thunder.
U	Ugly threatening appearance in the weather.
V	Visibility of distant objects, whether the sky be cloudy or not.
W	Wet dew.

NOTE: A bar (–) under any letter augments its signification.

DEFINITIONS COMMON TO NAVIGATION.

1. A Sphere is a round body, every point on the surface of which is equally distant from the centre of the body.

2. A Great Circle is the circumference of any section of a sphere, whose plane bisects the sphere, and passes through its centre.

3. A Small Circle is the circumference of any section of a sphere, whose plane does not bisect the sphere, nor pass through its centre.

4. The Arc of a Circle is any part or portion of the circumference of a circle.

5. The Distance between any two points on the surface of a sphere is measured on an arc of a great circle.

6. The Poles of the earth are the ends of the axis around which it revolves.

7. The Equator is a great circle which circumscribes the earth at a uniform distance of 90° from both poles.

8. The Meridians are great circles which cut the equator at right angles, and pass through both poles.

9. The Tropics of Cancer and Capricorn are small circles which circumscribe the earth parallel to the equator, at a distance of 23° 28′ north and south respectively.

10. The Arctic and Antarctic Circles are small circles which circumscribe the earth parallel to the equator, at a distance of 23° 28′ from either pole, or 66° 32′ north and south respectively.

11. Parallels of Latitude are small circles which circumscribe the earth parallel to the equator.

12. Latitude is distance north or south from the equator measured on a meridian.

13. Longitude is the arc of the equator between the first meridian and the meridian of any given place.

14. The Ecliptic is a great circle representing the apparent annual course of the sun among the fixed stars.

15. The Visible Horizon is a circle which limits the observer's view at sea.

16. The Sensible Horizon is a plane which touches the earth at the position of the observer.

17. The Rational Horizon is a great circle passing through the centre of the earth, whose plane is parallel to the sensible horizon.

18. The Zenith is that point which is vertically over the observer, and is 90° distant from all parts of the sensible or rational horizons.

19. Vertical Circles are great circles passing through the zenith, and cutting the horizon at right angles.

20. The Prime Vertical is the vertical circle which passes through the zenith, and cuts the horizon in the east and west points.

21. The Zenith Distance of a celestial object is the arc of a vertical circle contained between the object and the zenith of the observer.

22. The Meridian Altitude of a celestial object is its distance above the horizon, measured on the arc of a vertical circle when the object is on the meridian.

23. The Azimuth of a celestial object is the arc of the horizon between the north or south points, and a vertical circle passing through the object.

24. The Amplitude of a celestial object is the arc of the horizon between the east or west points and the centre of the object when rising or setting.

25. The Declination of a celestial object is the arc of a celestial meridian between the celestial equator or equinoctial and the object. The declination is north or south, according as the object is on the north or south side of the equinoctial.

26. The Polar Distance of a celestial object is the arc of a celestial meridian between the elevated pole and the object.

27. The Right Ascension of a celestial object is the arc of the equinoctial between the celestial meridian passing through the object, and the celestial meridian passing through the first point of Aries.

28. The Hour Angle of a celestial object is the angle at the pole, between the celestial meridian passing through the object and the meridian of the observer, measured on an arc of the equinoctial, and converted into time.

29. Dip or Depression of the horizon is the angle at the eye of the observer between the visible and sensible horizons.

30. Refraction is the deflection of a ray of light towards the centre of the earth, when passing obliquely from one transparent medium to another.

31. Parallax is the angle at the centre of a celestial object, subtended by a line joining the centre of the earth and the position of the observer.

32. Semi-diameter of a celestial object is the angle at the eye of the observer subtended by half the diameter of the object.

33. Augmentation of the Moon's Semi-diameter is the apparent increase in the semi-diameter of the moon, owing to her nearer approach to the observer as her altitude increases.

34. Observed Altitude is the observed angular height of an object above the visible horizon.

35. Apparent Altitude is the apparent angular height of an object's centre above the sensible horizon.

36. True Altitude is the true angular height of an object's centre above the rational horizon.

37. Civil Time is used to record events in ordinary life. The day commences at midnight and terminates at the following midnight. It is divided into two divisions of 12 hours each, the first being termed A.M. (ante meridiem) or before noon, the latter P.M. (post meridiem) or afternoon.

38. Astronomical Time is used in all astronomical calculations. The day commences at noon and terminates at the following noon, without the distinction of A.M. and P.M.

39. Sidereal Time is reckoned from the passing of the first point of Aries across the meridian. The day is consequently the time which the earth takes to make one revolution on its axis, viz., 23 H. 56 M. 4·09 S.

40. Apparent Time is the angle at the pole, between the meridian which passes through the sun and the meridian of the observer, reckoned westerly.

The Apparent Solar Day is consequently the time which elapses, between the departure of the sun from the meridian of a place (or apparent noon) and his return to the same meridian; it is a period of unequal duration, because the sun moves in the ecliptic and not in the plane of the equator, and thus causes a daily change in his position relative to the earth which sensibly affects his apparent velocity.

41. Mean Time is a uniform period used for convenience, on the supposition that the sun moves in the plane of the equator instead of in the ecliptic.

The Mean Solar Day is consequently the average or mean of all the apparent solar days in the year.

42. Equation of Time is the difference between apparent and mean time.

43. Variation of the Compass is the angle the magnetic meridian makes with the true meridian.

44. Deviation of the Compass is the angle the compass needle makes with the magnetic meridian.

45. The Error of the Compass is the angle the compass needle makes with the true meridian.

46. True Course is the angle a ship's track makes with the true meridian.

47. Magnetic Course is the angle a ship's track makes with the magnetic meridian.

48. Compass Course is the angle a ship's track makes with the compass needle.

49. Leeway is the angle a ship's track makes with the fore and aft line of the vessel.

50. The Complement of an arc or angle is the quantity by which the angle differs from a quadrant or 90 degrees.

51. The Supplement of an arc or angle is the quantity by which the angle differs from a semicircle or 180 degrees.

TERRESTRIAL MAGNETISM.

The Earth represents an enormous magnet whose two poles were in 1835 respectively situated in latitude 70° 5′ N., longitude 96° 45′ W., and latitude 73° 30′ S., longitude 147° 30′ E. These magnetic poles travel round the true poles of the earth at a radial distance of nearly 1,200 miles and carry along with them the entire system of terrestrial magnetism in a direction contrary to that in which the earth revolves, the system performing one entire

revolution in every 960 years; thus, as the magnetic needle on the meridian of Greenwich pointed to the true north pole of the earth in the year 1659, it follows that it will be on the intermediate 180th meridian in the year 2,139, and again on that of Greenwich in the year 2,619; hence the continual change in the variation of the needle as shown on the Chart of the Curves of Equal Magnetic Variation, published by order of the Admiralty. Now, as poles of contrary names *attract*, and of similar names *repel* one another, it follows that the north magnetic pole of the earth and the north pole of a magnetic needle cannot both contain north magnetism, because they are attracted towards one another; therefore, to avoid confusion, that pole of an artificial magnet which is attracted towards the astronomical north is said to contain south or *red* magnetism, and that pole which is attracted towards the astronomical south is said to contain north or *blue* magnetism.

Thus, the North magnetic pole of the earth contains north or *blue* magnetism, and the South magnetic pole contains south or *red* magnetism.

The Magnetic Meridian of a place is a vertical plane which passes through the two poles of a magnetic needle at the place.

The Variation or *declination* of the magnetic needle is the angle which the magnetic meridian makes with the true meridian of a place.

The Dip or *inclination* of the needle is the vertical angle which the magnetic needle makes with the plane of the horizon.

The Magnetic Equator, or *line of no dip*, is a somewhat sinuous line near the equator and crossing it in two places where the needle is horizontal: this line constitutes the division between the Northern and Southern magnetic hemispheres.

North of the magnetic equator the *red* end of the

dipping needle is pulled downwards, and the *blue* end repelled upwards, gradually increasing the inclination with the increase of the latitude, till at the magnetic pole the dip is 90 degrees.

South of the magnetic equator the *blue* end of the needle is depressed, and the *red* end elevated, till at the south magnetic pole the needle is again vertical.

The sun has considerable influence on the magnetism of the earth, inasmuch as the magnetic force is greater in both hemispheres in the months of December, January, and February, when the sun is nearest to the earth, than in the months of May, June, and July, when more distant. The mean solar parallax is 8·760 seconds, which corresponds to a mean distance of 93,300,000 miles.

The daily passage of the sun across the meridian has a perceptible influence on the magnetic needle; thus, the *red* end of the needle travels from east to west with the sun, from sunrise till nearly 2 P.M., from which time till about 10 P.M. it gradually recovers itself. The mean of these diurnal variations throughout the year in the latitude of the English Channel is about 12 minutes, though they have been known at Paris to reach 25 minutes, and sometimes in the Arctic regions even 2½ degrees; near the equator the oscillations entirely cease.

The Aurora Borealis and the Aurora Australis both cause variations of the needle, which sometimes in our latitudes amount to 20 minutes, while in polar regions the needle frequently oscillates several degrees; its irregularity is considerable on the day before the occurrence of the phenomenon.

Magnetic storms also exercise considerable influence on the needle: it has been established by Sabine that these disturbances attain their greatest frequency about every ten years, and that those periods of maximum magnetic disturbance coincide with the periods when *sun spots* attain their greatest number and size.

DESCRIPTION OF THE STANDARD COMPASS.

The Standard Compass is the only compass by which a ship should be navigated. It should be used for azimuths, amplitudes, stellar observations, and in taking bearings of the land. All other compasses, such as the steering compass, bridge compass, and mast-head or tripod compass, are to be considered only as supplementary to the standard compass.

In selecting a position for this compass, the vicinity of vertical iron, or of any considerable mass of iron, must be guarded against; and no portable pieces of iron subject to occasional removal permitted to be placed within a radius of say 15 feet. The standard or column must be permanently fixed in the middle line of the vessel as near to the neutral point of local magnetic attraction as can conveniently be arranged. The advantage of ascertaining a neutral point, where the local attraction is scarcely felt in any direction of the ship's head, is well worth the trouble of experiment.

In an iron ship, built head north, the standard compass ought to be placed as far forward as convenient: if built head south it should be placed as far aft as convenient, but not too near the rudder-post or steering-gear; if built head east or west it should be placed nearly amidships.

The compass-bowl should be made of pure copper of considerable thickness, and placed at such a height above the deck that bearings of distant objects can be observed over the bulwarks or deck-houses with perfect ease.

The two needles must be fixed parallel to one another under the card at a distance of from 50 to 60 degrees apart, that is, the extremities of each needle should be from 25 to 30 degrees from the north and south points of the card respectively. They should be deep vertically, but narrow, in order that the direction of magnetic force may coincide with their middle lines.

The centre or cap should be fitted with a ruby or sapphire, and supported on a pivot of hardened steel, gilded, to preserve from rust.

Spare cards should be kept in pairs, the north and south ends together, or connected by small pieces of soft iron, to preserve their magnetic power.

It is a mistake to suppose that large compasses are better than small ones. No compass card should exceed 8 or 9 inches diameter, the Admiralty Standard size being $7\frac{1}{2}$ inches. Less even than this might be preferable, on account of the increase of accuracy gained by the decrease in size. This is accounted for by the fact, that the increase in the weight of the larger needles with their card and other fittings, is proportionally greater than the increase of magnetic force gained, and is consequently accompanied by longer and slower oscillations; in other words,—the smaller needles have the advantage of being more easily attracted to the magnetic pole, and on account of their extreme lightness, they more easily retain that position. Another advantage of the short needles is, that the jewel, the pivot, and every working part experiences greater immunity from friction. It is urged against small cards that they are more difficult to read than large ones; it therefore resolves itself into the question, whether it is better to steer to degrees from a comparatively *incorrect* card, or to steer to quarter points from a comparatively *correct* card.

DESCRIPTION OF SIR WILLIAM THOMSON'S COMPASS.

In size and outward appearance this compass does not differ from those hitherto in use; but the card is constructed on an entirely new principle. It consists of a central aluminium boss and an outer aluminium rim connected together by fine silk cords. Small magnets

from 2 to 3 inches long are suspended by means of silk cords from the rim, and thin paper marked with the points of the compass and degrees, is attached to the rim and partially supported by the silk cords between the rim and the boss. By this arrangement the principal part of the weight is in the aluminium rim, and is consequently as far as possible from the centre on which the card moves. This gives a very long period of free oscillation, which, from mathematical reasoning, is known to give great steadiness.

The card with the needles is extremely light; the 10-inch compass weighing 178 grains, which is about a twentieth of the weight of an ordinary compass of the same dimensions. The frictional error is thus reduced to a very small amount.

To correct a quadrantal error of 5 or 6 degrees, according to the Astronomer Royal's method, a 10-inch compass of ordinary construction would require about two tons of soft iron, if the correction is to be true in all latitudes. The smallness of the needles in the new compass allows the perfect correction for all latitudes, of a quadrantal error of 5 or 6 degrees for a 10-inch compass, and 11 or 12 degrees for a 7-inch compass, by a couple of iron globes, each not more than 6 inches diameter, fixed on the two sides of the binnacle.

The semi-circular error is corrected by applying two adjustable magnetic correctors, one for neutralising the athwart-ship component, the other the fore-and-aft component of the ship's magnetic force.

The heeling error, chiefly experienced in iron sailing ships, is corrected by the application of an adjustable magnet below the compass, in a line through its centre perpendicular to the deck.

For taking bearings, whether of sun or stars, or of lighthouses, beacons, or landmarks, a new instrument called the Azimuth Mirror is provided. This instru-

ment facilitates very much the taking of star azimuths, by throwing (as in the *camera lucida*) an image of the star upon the graduated circle of the compass card, or, more properly speaking, on a virtual image of this scale at an infinite distance, as seen through a convex lens. It is easy at sea, even when the ship has considerable motion, to read the position of a star accurately to a small fraction of the white space on the card between two degree divisions on which its image is seen. The focal length of the convex lens is a little greater than the radius of the circle, and thus for objects on the horizon, or at any altitude not exceeding 30°, no further adjustment of the azimuth appliance than to bring the object fairly into the field of view, is required.

Another improvement which allows the compass-bowl always to keep a truly level position, is the use of knife edges instead of journals for supporting the gimbals. For taking azimuths accurately it is most important that the compass-bowl should be truly level, but when a compass is supported on journals the friction between the journals and supports is very injurious in preventing it from keeping the level position. When knife edges are used for the axes of the gimbals, the bowl takes a level position with almost perfect accuracy. A hemispherical hollow space below the glazed case in which the compass works, nearly filled with castor oil, serves to calm the vibrations of the bowl, which, without this appliance, would sometimes be troublesome owing to the want of friction in the knife edge bearings. The gimbals are suspended from a wire grummet ring, still further to reduce vibration.

DESCRIPTION OF THE FLINDERS-BAR.

The Flinders-bar supplied with Sir William Thomson's Compass, is a round bar of soft iron, 3 inches in diameter, and of whatever length from 6 to 24 inches, is found to be proper for the actual position of the compass in any particular ship. To make up the proper length, it is supplied in pieces of 12, 6, 3, and $1\frac{1}{2}$ inches, also two pieces of $\frac{3}{4}$ of an inch. In making up the proper length, the longest piece should be uppermost, and the others below in the order of their lengths. The weight of the bar is supported on a wooden column resting on a bracket, fixed near the foot of the binnacle; this wooden column being cut to such a length, or so made up of pieces, as to give the proper height to the upper end of the iron bar. The compound column of iron and wood is kept in position and protected from rain and spray by a brass tube with upper end closed.

The main object of the Flinders-bar is to counterbalance the component of the ship's horizontal force on the compass, which is due to magnetism induced by the vertical component of the terrestrial magnetic force. Hence, in all ordinary cases, the ship's iron being symmetrical on the two sides of the fore-and-aft midship vertical plane, and the compass being placed in this plane, the Flinders-bar must be placed in it also, exactly in the middle of the front or back of the binnacle. The Flinders-bar essentially corrects, wholly and permanently, the Heeling error, which has maximum value on the East and West courses, and vanishes on the North and South courses. This error is due to horizontal force produced by magnetism, induced by force perpendicular to the deck. It is towards the lower side of the ship on a West course, if towards the upper side on an East course; or is towards the upper side on a West course, if towards the lower side on an East course.

A subordinate object of the Flinders-bar is to partially correct the Heeling error, which has equal maximum value when the ship's head is North or South, and is zero when the ship's head is East or West, by partially counterbalancing the component force on the compass, perpendicular to the ship's deck, exerted by that part of the ship's magnetism which is induced by the vertical component of the earth's magnetic force. When it is not desired to make this contribution to the heeling correction by the Flinders-bar, it should be placed with its top about two inches above the level of the needles of the compass card. A large part of this error depends on the upper parts of the ship's iron having on the whole a polarity, which, for a ship built in the Northern Magnetic Hemisphere, and continuing in the same Hemisphere, is the polarity (*blue*) of a true North Pole, while the bottom of the ship and keel have, on the whole, a polarity of the opposite kind (*red*). The remainder is due to inductive magnetization, by the vertical magnetic force of the earth acting on iron deck beams or iron decks, when inclined to the horizon by the ship heeling over to either side. The combined effect of these influences is to draw the North point of the compass card towards whichever side of the ship is the highest as she heels over, if she is on any other course than due East or West. It is to be corrected at sea, by placing the HEELING MAGNET with its true South pole (*red*) up, and true North pole (*blue*) down, in the central tube of the binnacle below the middle of the compass, and sliding it up or down till it is found that changes of the ship's inclination, without changes of course, produce no sensible disturbance on the compass.

This adjustment should not be attempted unless the ship's course is within 60° of either North or South; with this limitation it may be usefully performed at any time when good bearings, whether of sun, moon or stars,

can be had. If when the ship heels steadily over to either side, the North point of the compass shows a deviation towards the upper side of the ship, the HEELING MAGNET if *red* end up is to be moved up a little, or if *blue* end up to be moved down. If, on the contrary, the North point of the compass shows a deviation towards the lower side of the ship, the HEELING MAGNET must be moved downwards if its *red* end is up, or upwards if its *blue* end is up. If the ship crosses the magnetic equator, it may be found necessary to reverse the HEELING MAGNET.

A Clinometer (little pendulum) attached to the binnacle facilitates this adjustment, by allowing the amount of every variation of the ship's heeling inclination to be seen along with the deviation of the compass produced by it.

To understand the action of the Flinders-bar, suppose the ship to be anywhere in the northern magnetic hemisphere, the vertical force there is such as to pull the *red* end or pole of a magnetized needle downwards, and to repel the *blue* end upwards. It also has the effect of inducing magnetism in any mass of iron, so as to give it a transient magnetic quality marked with *blue* on the upper side or end, and *red* on the lower side or end. Thus, in the northern magnetic hemisphere, the Flinders-bar is transiently magnetized by the earth's vertical force in such manner that it acts like a great bar magnet, with its upper end *blue* and its lower end *red*. At the magnetic equator it loses its magnetism, and in the southern magnetic hemisphere it acquires magnetism in the opposite direction to that which it had in the northern hemisphere; so that its upper end becomes *red* and its lower end *blue*. As the ship moves from one hemisphere across the magnetic equator to the other, the magnetism of the Flinders-bar gradually diminishes to zero, and then increases gradually in the contrary direction.

The object to be attained in applying it to the binnacle is, that, with this gradual change of its magnetism, it

shall always as exactly as possible counterbalance the changing part of the force on the compass, due to the part of the ship's magnetization which changes with the gradual change of a vertical component of the terrestrial magnetic force. If this changing part of the ship's disturbing force on the compass is a pull aft in the northern magnetic hemisphere, and a pull forward in the southern magnetic hemisphere, the Flinders-bar must be on the forward side of the binnacle. On the other hand, if the regularly changing part of the ship's force be a pull forward in the northern hemisphere, and aft in the southern hemisphere, the Flinders-bar must be on the after side of the binnacle.

The former is the most frequent case for the Standard compass and the steering compasses of modern merchant steamers in which the conning and steering of the ship is done on a bridge forward of the engines, with considerably more than half the ship behind it. It is almost certain to be the case with an after steering compass, a few feet in advance of the top of the stern post and rudder head, in an iron steamer or sailing ship. The second above-mentioned case is what will generally be found with a compass placed anywhere in the after half of the ship's length, to within six or eight feet of the stern post. Generally it is impossible to ascertain which of the two is the actual case until the ship has made a voyage through regions presenting considerable differences of vertical magnetic force.

The best plan generally is, in first placing the binnacle on the deck, to turn it with the fittings of the Flinders-bar forward or aft, according as it is found that the fore-and-aft correcting magnets have to be placed with *red* or *blue* poles forward or aft. It may be that the experience of a first voyage may show that the binnacle must be turned the other way to get the Flinders-bar into its right position, but the chances of this being necessary are

reduced if the binnacle is originally placed according to the preceding rule.

In the first adjustment, or when there is knowledge as to the proper proportion of correction to be made by the Flinders-bar, it may be set to correct about half the error on East and West courses; the remainder must be accurately corrected by the fore-and-aft magnets.

Suppose now the first adjustment to have been made somewhere in the northern magnetic hemisphere, and suppose that as the ship goes to places of weaker vertical force the fore-and-aft correcting force required to make the compass correct on East and West courses is found to be less than at the beginning of the voyage, then it is clear that part of the correction made by the magnets ought to have been made by the Flinders-bar. But nothing need be done except to diminish the fore-and-aft pull by the magnets, as long as the ship is going to places of weaker vertical force. If without touching or crossing the magnetic equator the ship returns again to places of stronger vertical force, and if it is found that increased longitudinal pull is now required, this should be applied, not by the magnets, but by introducing a Flinders-bar or by increasing the bar already in position.

Generally, for a ship making passages to and fro through regions of considerably different vertical force, whether she crosses the magnetic equator or not, the rule in respect of the fore-and-aft correction is as follows :—

CORRECT THE DEVIATIONS FOUND BY OBSERVATION ON THE EAST OR WEST COURSES BY THE FORE-AND-AFT MAGNETS WHEN THE SHIP IS GOING TO PLACES OF WEAKER VERTICAL FORCE; AND BY THE FLINDERS-BAR WHEN SHE IS GOING TO PLACES OF STRONGER VERTICAL FORCE, WHETHER IN THE NORTHERN OR SOUTHERN HEMISPHERE.

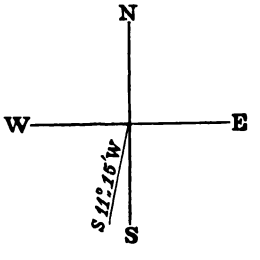
DEVIATION OF THE COMPASS IN IRON SHIPS.

Deviation is the amount the compass needle is drawn out of the magnetic meridian by the attraction of the iron in the ship. It is said to be East, when the north point of the compass card is drawn to the eastward or right, and West, when it is drawn to the westward or left of the magnetic meridian.

The terms East and West deviation are applied in precisely the same manner as East and West variation, that is, looking from the centre of the compass, apply East deviation to the right and West deviation to the left of the magnetic course to get the course to steer, and *vice versâ*.

Magnetic Course	= N 4° E.	Course steered by Compass	= North.
Deviation of Compass	= 4° W.	Deviation of the Compass	= 4° W.
True Course to Steer	= North.	Magnetic Course	= N. 4° E.

Deviation is determined, when in port, by finding the difference between the correct magnetic bearing of some distant object, and its bearing from on board. The object should be at such a distance from the ship, say from 6 to 10 miles, that the diameter of the space through which she revolves shall make no sensible difference in the real bearing of the object. The deviation thus obtained is said to be Easterly when the correct magnetic bearing is to the right, and Westerly when to the left of the bearing from on board.



EXAMPLE
Correct Magnetic Bearing = S. 11° 15′ W.
Standard Compass Bearing = South.
Deviation = 11° 15′ E.

In the event of no suitable object being available, deviation is determined by reciprocal bearings, that is,

by landing a compass in a place free from the influence of volcanic rock or large masses of iron, and observing the mutual bearings of the shore and standard compasses from each other, at the moment when the ship's head is steady on each point successively.

The difference between the shore bearing *reversed*, and the standard compass bearing, is the deviation.

Deviation is determined at sea, by finding the true bearing of some celestial body by Azimuths or Amplitudes; the variation on the chart applied to the true bearing so determined, will give the correct magnetic bearing of the body, the difference between which and its bearing from on board will be the deviation for that direction of the ship's head.

When the ship's head is brought to one point, the deviation for that point only can be determined, but if the ship's head is brought to a number of points, the deviations for all the points of the compass may be determined.

For accuracy, the ship's head should be brought to at least eight points equally distributed round the compass.

When sailing along a well known coast, the deviation may be found by observing the bearing of two well defined objects in one straight line from the standard compass, the difference between which and their bearing from one another on the chart will be the deviation.

The deviation changes in any considerable change in the latitude of the ship, it changes for some time in a newly built ship, or, if the ship has been lying for any length of time with her head in one direction and then has her position altered, it also changes as the ship heels to starboard or port.

It is advisable to test the table of deviations at every available opportunity.

The heeling error is greatest when the ship's head is magnetic north or south, it vanishes when the ship's head is magnetic east or west.

In the majority of iron ships, while the ship is in the northern hemisphere and the compass above the upper deck, the north point of the compass is drawn to windward as the ship heels. If the ship is kept steady on one compass course, she will be found to windward of her supposed position when on northerly, and to leeward when on southerly courses. If the ship is kept steady on a fixed point in the horizon, she will appear by compass to fall off as she heels on northerly, and to come up on southerly courses.

In steering by compass, in order to make good a given compass course, keep away on either tack as the ship heels when on northerly courses, and keep closer to the wind on either tack when on southerly courses.

Ships which have the north point of the compass drawn to windward in the northern hemisphere, will, especially in high southern latitudes, have it drawn sensibly to leeward.

In the northern hemisphere iron ships should be built head south magnetic, or nearly so, as the part of the ship on line of upper deck which is north in building is much less strongly magnetized than the part which is south.

To neutralize the large deviations found in iron ships, provide two powerful magnets, and draw two lines on the deck directly under the centre of the compass intersecting one another at right angles, the one line running fore and aft, the other athwartship.

Place the ship's head correct magnetic north or south and place one of the magnets on or below the deck, with its centre on the fore and aft line, and parallel to the athwartship line: if the north point of the compass is attracted towards the starboard side, place the *blue* end of the magnet to port, and *vice versâ*, then move the magnet to or from the compass until the needles point correct magnetic north or south. Then place the ship's head

correct magnetic east or west, and place the other magnet on or below the deck, with its centre on the athwartship line, and parallel to the fore and aft line; if the north point of the compass is attracted towards the stern, place the *red* end of the magnet aft, and *vice versâ*, then move the magnet to or from the compass until the needles point correct magnetic east or west. Then bring the ship's head to one of the intercardinal points N.E., S.E., S.W., or N.W., correct magnetic, and put as much soft iron chain in the boxes as will overcome the quadrantal deviations. These adjustments must be made with the ship perfectly upright.

To compensate for the heeling error, put the ship's head magnetic north or south, and heel her over as far as practicable; if the north point of the compass is drawn to windward, keep the *red* end of a vertical magnet placed in the centre of the pillar of the binnacle uppermost, but if to leeward, the *blue* end, and move the magnet up or down immediately under the centre of the compass until the needles point correctly.

As it is difficult, and often impracticable, to heel the ship, the error may be corrected as follows:—Having found the time in which a dipping needle placed on shore, and deflected say 20 degrees in an east and west plane, will take to make ten vibrations; place the same instrument in the binnacle on board, with its centre in the position of the point of suspension of the compass needles; place the ship's head magnetic east or west, and having deflected the needle as before, move the vertical magnet up or down as the case may be until the time due to ten vibrations corresponds with that previously found on shore, then fix the magnet.

Although compasses may be adjusted by magnets before a ship sails, and the adjustment hold good for that locality, yet as the ship changes her position, and alters not only the variation but the dip of the needle, the

relative forces of magnetism alter also, and the corrections cease to be reliable.

Many fine vessels have been lost, while others have found themselves far out of their reckoning, in consequence of too little time having been given for observations to verify the Steering Tables, and too little attention paid to the following simple Rules :—

After steering for some time on *easterly* courses, expect easterly deviation if you turn to the north, or westerly deviation if you turn to the south.

After steering for some time on *westerly* courses, expect westerly deviation if you turn to the north, or easterly deviation if you turn to the south.

The reason for this is, that true northern polarity (*blue*), or true southern polarity (*red*), induced in the starboard and port ends of deck beams, and starboard and port sides of ships, while steering east or west, remains for some time after she has altered course to north or south.

This warning is particularly important for ships of war, after firing guns when on easterly or westerly courses, if the course is then changed to north or south; and more particularly if the change of course is effected under canvas, without the shaking of the ship's magnetism produced by the action of the engines and propeller.

The warning is also important for ships steaming through the Mediterranean eastwards or westwards, and then turning south, through the Suez Canal, or north, round Cape St. Vincent; and for ships steaming eastward from America, and then turning northwards or southwards into St. George's Channel.

DEVIATION BY THE BEARING OF A DISTANT OBJECT.

The method of determining the deviations of the standard compass, by finding the correct magnetic bearing of a distant object, and hence the deviations, is as follows: Place the ship's head by the standard compass on the eight cardinal points, and observe the bearing of a distant object, say ten miles off, as she steadies on each point successively, then tabulate the results as in the subjoined forms, and find the correct magnetic bearing of the object (if not already found by taking the compass ashore) by the following rule: When the bearings are all of one name, add them together, and divide by 8, the result is the correct magnetic bearing of the same name as the standard compass bearings.

If some bearings are north and some south, subtract the less number from 180 degrees, so that all the bearings will be of one name, then divide by 8, the result is the correct magnetic bearing.

If the bearings are all north or all south, while some are east and some west, add all the easts together, then the wests, substract the less from the greater sum, and divide by 8, the result is the correct magnetic bearing of the distant object, to be named after the greater sum.

The difference between the correct magnetic bearing thus found, and the observed bearings of the object by the standard compass on board, will give the deviations of the compass, which are named East when the correct magnetic bearing is to the *right*, and West when to the *left* of the bearing from on board.

TABLE A.

Correct Magnetic Bearing = N 77° W.

Ship's Head by the Standard Compass.	Bearing of Distant Object by the Standard Compass.				Deviation of the Standard Compass.		
		°	′		°	′	
North.	N	79	0	W	2	0	E
N.E.	S	77	0	W	26	0	E
East.	S	78	0	W	24	0	E
S.E.	N	87	0	W	10	0	E
South.	N	75	0	W	2	0	W
S.W.	N	64	0	W	13	0	W
West.	N	52	0	W	25	0	W
N.W.	N	54	0	W	23	0	W

TABLE B.

Correct Magnetic Bearing = S 11° 15′ W.

Ship's Head by the Standard Compass.	Bearing of Distant Object by the Standard Compass.				Deviation of the Standard Compass.		
		°	′		°	′	
North.	S	7	15	W	4	0	E
N.E.	S	24	15	W	13	0	W
East.	S	33	45	W	22	30	W
S.E.	S	32	45	W	21	30	W
South.	S	19	15	W	8	0	W
S.W.	S	5	15	E	16	30	E
West.	S	13	30	E	24	45	E
N.W.	S	8	30	E	19	45	E

DESCRIPTION OF AZIMUTH TABLES.

One of the best methods of determining the deviation is to apply the sun's true bearing or azimuth to the sun's bearing by compass, corrected for variation at the position of the ship. Davis's azimuth tables are computed between the parallels of latitude 30° N. and 30° S. inclusive, while those by Burdwood take in from 30° to 60°. They are identical in arrangement, and one description applies to both

The azimuths are not given when the altitude of the sun exceeds 60°, as greater dependence can be placed on the observation when the body has a low altitude. The time and bearing given in the tables refer to the sun's centre; but as, from the effect of refraction, the sun's centre at rising or setting is elevated about 33 minutes above the horizon, it becomes necessary to take its bearing when the lower limb is 16 minutes, or the semi-diameter, above the horizon.

In determining the deviation it is obvious that the difference between the sun's true bearing, or azimuth, and the sun's bearing by compass will give the variation for that position of the ship's head. The deviation will therefore be the difference between the variation thus observed and the variation obtained from the "Chart of the Curves of Equal Magnetic Variation." This chart is a most important adjunct to navigation, as it not only supplies, by inspection, the variation due to any geographical position on the globe, but it shows at a glance those parts of the ocean where great differences of variation occur, within limited areas; for example, in running up the English Channel from the westward—say from the neighbourhood of Cape Clear to the Downs (a distance of about 480 miles), the variation changes 6 degrees, or fully half a point, which necessitates watchfulness and periodical alterations in the courses steered.

DIRECTIONS FOR USING THE TABLES.

Turn to the pages indicating the latitude of the ship, then under the column of declination and along the line of the object's hour angle find its true bearing, or azimuth, reckoned from the elevated pole, viz., from north in latitude north, from south in latitude south, and towards east or west, according to instructions at the foot of each page. Thus (Burdwood, page 179), in latitude 47° North., with sun's declination 18° S., at 9h. 24m. A.M. the sun's true bearing is N. 141° 27′ E., or at 2h. 36m. P.M. it is N. 141° 27′ W. If the compass bearing requires it, this can be reckoned from the depressed pole by subtracting from 180°, so that N. 141° 27′ E. becomes S. 38° 33′ E. Example :—

7th October, 1880. Steering East.

Latitude, ...	49° 0′ N.	Declination,.....	5° 45′ S.
Longitude,...	10° 0′ W.	Apparent time,	8h. 56m. A.M.
Bearing of sun by standard compass,.....			S. 39° 30′ E.
Or, reckoning from the elevated pole,.....			N. 140° 30′ E.
Variation, as shown on the chart (1880),..			22° 50′ W.

Required, the Deviation of the Standard Compass.

Sun's true bearing by tables,.....	N. 122° 20′ E.
Sun's bearing by compass, ...	N. 140° 30′ E.
Variation observed in ship,..	18° 10′ W.
Variation from the chart,.....,.....	22° 50′ W.
Deviation with ship's head East, ...	4° 40′ E.

NAPIER'S DEVIATION DIAGRAMS.

The following method of finding the deviations of the compass is due to James R. Napier, F.R.S., and consists of two parts, namely, the printed diagram and the curve which is filled in by hand. It has the advantage of being equally useful whether the observations have been made on equidistant points or not. The diagram consists of a

vertical line of about 18 inches in length, divided into 32 equal parts, representing the 32 points of the compass, commencing at the top with north. The line is also divided into 360 equal parts representing degrees, which are numbered from 0° at the top to 360° at the bottom.

These divisions are also numbered, according to the usual mode of dividing the circumference of the compass card, from 0° at north and south, to 90° at east and west. The line may, in fact, be considered as the margin of a compass card cut at the north point and straightened. The vertical line is intersected at each of the 32 points by two straight lines inclined to it at angles of 60°, one a *plain* line dipping to the left, the other a *dotted* line dipping to the right.

The least number of observed deviations available for obtaining a complete curve is the deviation on 4 points distributed equally, or nearly so, round the compass; but, if possible, the deviations should be observed on 8 or more points.

If the deviations are observed on 4 points only, these should be at or near N.E., S.E., S.W., and N.W.

The points next in importance are North, East, South, and West.

Cases may also occur in which by the ship swinging round at her anchor in a tide-way, or to the wind, or by the aid of a steam-tug, the deviations may be observed on various directions of the ship's head, not being necessarily exact points of the compass; or similarly whilst under steam or sail at sea, a number of azimuths of the sun may be observed, and hence the deviation obtained.

In these cases, the method here described furnishes a ready and effectual mode of obtaining a result in which the errors of individual observations are as far as possible compensated, and any egregious errors eliminated.

The observed deviations are to be laid down on the diagram in the following manner,—take, on the vertical line, one of the compass courses on which an observation has been made, and lay off the amount of the observed deviation on the *dotted* line which passes through it, or if no *dotted* line passes through it, then in a direction parallel to the *dotted* lines, to the right if the observed deviation be easterly, to the left if westerly, and mark the point so determined with a cross or dot in ink. Perform the same operation for each observed deviation, then with a pencil and a light hand draw a flowing curve, passing as nearly as possible through all the crosses or dots; and when satisfied with the curve in pencil, draw it in ink.

The deviations thus laid off on the diagram can be readily applied to the ship's courses by the two following methods:—

1st.—From the compass course which has been steered to find the corresponding magnetic course to be laid off on the chart.

On the vertical line take the compass course. Move in a direction parallel to the *dotted* lines till you arrive at the curve, and then move in a direction parallel to the *plain* lines till you get back to the vertical line.

The point on the vertical line at which you arrive is the magnetic course required.

EXAMPLE.—With the deviations as in Table A, laid off on Diagram A.

Assuming the courses steered by the standard compass to have been North, N.W., N.N.E., the corresponding correct magnetic courses to be laid off on the chart would then be respectively, N. 2° E., N. 67° 30′ W., N. 41° E.

Again,—With the deviations as in Table B, laid off on Diagram B.

Assuming the courses steered by the standard compass to have been N.E. by E., W. by N., N.N.W., the corresponding correct magnetic courses to be laid off on the chart would then be respectively, N. 40° E., N. 54° W., N. 41° W.

2nd.—From the magnetic course as laid off on the chart, to find the corresponding compass course on which to keep the ship's head.

On the vertical line take the given magnetic course. Move in a direction parallel to the *plain* lines till you arrive at the curve, and then move in a direction parallel to the *dotted* lines till you get back to the vertical line.

The point on the vertical line at which you arrive is the compass course required.

EXAMPLE.—With the deviations as in Table A, laid off on Diagram A.

Assuming the correct magnetic courses laid off on the chart to be East, S.E., West, the corresponding courses to steer by the standard compass would then be respectively, N. 62° E., S. 61° 30′ E., N. 63° W.

Again,—With the deviations as in Table B, laid off on Diagram B.

Assuming the correct magnetic courses laid off on the chart to be E. by S., S.S.W., N.E., the corresponding courses to steer by the standard compass would then be respectively, S. 56° E., S. 19° 30′ W., N. 62° 45′ E.

The diagram can also be used for finding the correct magnetic bearings of distant objects as follows :—

Place one leg of the dividers on the vertical line at the position of the ship's head by the standard compass, and

let the other leg take the curve at a point parallel to the nearest *dotted* line, the distance contained in the dividers when applied to the vertical line will give the deviation of the compass for that direction of the ship's head, which, when applied in the usual manner to the bearing of the distant object by the standard compass, will give the correct magnetic bearing of the object.

Examples from Diagram A :—

Bearing by standard compass	N.E. by E. =	N. 56° 15′ E.
Deviation with ship's head at	N.N.W. =	12° 15′ W.
Correct magnetic bearing		N. 44° 0′ E.
Bearing by standard compass	N.W. by W. =	N. 56° 15′ W.
Deviation with ship's head at	N.N.W. =	12° 15′ W.
Correct magnetic bearing		N. 68° 30′ W.

Examples from Diagram B :—

Bearing by standard compass	S.E. by E. =	S. 56° 15′ E.
Deviation with ship's head at	S.W. by W. =	21° 0′ E.
Correct magnetic bearing		S. 35° 15′ E.
Bearing by standard compass	E. by N. =	N. 78° 45′ E.
Deviation with ship's head at	S.W. by W. =	21° 0′ E.
		N 99° 45′ E.
		180° 0′
Correct magnetic bearing		S. 80° 15′ E.

Steering Table constructed from Diagram A (Rule II.)

Magnetic Course proposed to be made.	Course therefore to be steered by Standard Compass in order to make the proposed Magnetic Course.			
	°	′		
North.	N. 1	0 W.	or about	North.
N. by E.	N. 5	0 E.	„	N.$\frac{1}{2}$E.
N.N.E.	N. 11	45 E.	„	N. by E.
N.E. by N.	N. 18	30 E.	„	N. by E.$\frac{3}{4}$E.
N.E.	N. 26	0 E.	„	N.E. by N.$\frac{3}{4}$N.
N.E. by E.	N. 33	45 E.	„	N.E. by N.
E.N.E.	N. 42	0 E.	„	N.E.$\frac{1}{4}$N.
E. by N.	N. 51	0 E.	„	N.E.$\frac{1}{2}$E.
East.	N. 61	45 E.	„	N.E. by E.$\frac{1}{2}$E.
E. by S.	N. 74	15 E.	„	E. by N.$\frac{1}{2}$N.
E.S.E.	N. 87	45 E.	„	E.$\frac{1}{4}$N.
S.E. by E.	S. 77	30 E.	„	E. by S.
S.E.	S. 60	30 E.	„	S.E. by E.$\frac{1}{2}$E.
S.E. by S.	S. 43	15 E.	„	S.E.$\frac{1}{4}$S.
S.S.E.	S. 27	15 E.	„	S.E. by S$\frac{1}{2}$S.
S. by E.	S. 12	0 E.	„	S. by E.
South.	S. 2	45 W.	„	S.$\frac{1}{4}$W.
S. by W.	S. 17	30 W.	„	S. by W.$\frac{1}{2}$W.
S.S.W.	S. 32	30 W.	„	S.W. by S.
S.W. by S.	S. 48	0 W.	„	S.W.$\frac{1}{4}$W.
S.W.	S. 63	30 W.	„	S.W. by W.$\frac{3}{4}$W.
S.W. by W.	S. 79	0 W.	„	W. by S.
W.S.W.	N. 87	0 W.	„	W.$\frac{1}{4}$N.
W. by S.	N. 74	45 W.	„	W. by N.$\frac{1}{4}$N.
West.	N. 63	30 W.	„	N.W. by W.$\frac{3}{4}$W.
W. by N.	N. 53	45 W.	„	N.W.$\frac{3}{4}$W.
W.N.W.	N. 44	30 W.	„	N.W.
N.W. by W.	N. 36	30 W.	„	N.W.$\frac{3}{4}$N.
N.W.	N. 28	45 W.	„	N.W. by N.$\frac{1}{2}$N.
N.W. by N.	N. 21	30 W.	„	N.N.W.
N.N.W.	N. 14	30 W.	„	N. by W.$\frac{1}{4}$W.
N. by W.	N. 8	0 W.	„	N.$\frac{3}{4}$W.

Steering Table constructed from Diagram B (Rule II.)

Magnetic Course proposed to be made.	Course therefore to be steered by Standard Compass in order to make the proposed Magnetic Course.			
	°			
North.	N. 7	0 W.	or about	N.$\frac{1}{2}$W.
N. by E.	N. 13	0 E.	,,	N. by E.$\frac{1}{4}$E.
N.N.E.	N. 30	30 E.	,,	N.E. by N.$\frac{1}{4}$N.
N.E. by N.	N. 47	30 E.	,,	N.E.$\frac{1}{4}$E.
N.E.	N. 63	0 E.	,,	N.E. by E.$\frac{1}{2}$E.
N.E. by E.	N. 77	0 E.	,,	E. by N.$\frac{1}{4}$N.
E.N.E.	N. 90	0 E.	,,	East.
E. by N.	S. 78	0 E.	,,	E. by S.
East.	S. 67	0 E.	,,	E.S.E.
E. by S.	S. 56	15 E.	,,	S.E. by E.
E.S.E.	S. 46	0 E.	,,	S.E.
S.E. by E.	S. 36	15 E.	,,	S.E.$\frac{3}{4}$S.
S.E.	S. 27	30 E.	,,	S.E. by S.$\frac{1}{2}$S.
S.E. by S.	S. 18	30 E.	,,	S. by E.$\frac{3}{4}$E.
S.S.E.	S. 10	0 E.	,,	S. by E.
S. by E.	S. 2	30 E.	,,	S.$\frac{1}{4}$E.
South.	S. 5	0 W.	,,	S.$\frac{1}{2}$W.
S. by W.	S. 12	15 W.	,,	S. by W.
S.S.W.	S. 19	0 W.	,,	S. by W.$\frac{3}{4}$W.
S.W. by S.	S. 26	0 W.	,,	S.W. by S.$\frac{3}{4}$S.
S.W.	S. 33	30 W.	,,	S.W. by S.
S.W. by W.	S. 41	15 W.	,,	S.W.$\frac{1}{4}$S.
W.S.W.	S. 50	0 W.	,,	S.W.$\frac{1}{2}$W.
W. by S.	S. 58	0 W.	,,	S.W. by W.$\frac{1}{4}$W.
West.	S. 67	30 W.	,,	W.S.W.
W. by N.	S. 77	30 W.	,,	W. by S.
W.N.W.	S. 88	15 W.	,,	W.$\frac{1}{4}$S.
N.W. by W.	N. 80	30 W.	,,	W.$\frac{3}{4}$N.
N.W.	N. 68	30 W.	,,	W.N.W.
N.W. by N.	N. 55	30 W.	,,	N.W. by W.
N.N.W.	N. 41	15 W.	,,	N.W.$\frac{1}{4}$N.
N. by W.	N. 25	0 W.	,,	N.W. by N.$\frac{3}{4}$N.

Table for converting Points, and Quarter Points of the Compass into Degrees, Minutes, and Seconds.

NORTH.		Points.	Degrees, &c.	Points.	SOUTH.	
			° ′ ″			
		0	0 0 0	0		
		¼	2 48 45	¼		
		½	5 37 30	½		
		¾	8 26 15	¾		
N. by E.	N. by W.	1	11 15 0	1	S. by E.	S. by W.
		¼	14 3 45	¼		
		½	16 52 30	½		
		¾	19 41 15	¾		
N.N.E.	N.N.W.	2	22 30 0	2	S.S.E.	S.S.W.
		¼	25 18 45	¼		
		½	28 7 30	½		
		¾	30 56 15	¾		
N.E. by N.	N.W. by N.	3	33 45 0	3	S.E. by S.	S.W. by S.
		¼	36 33 45	¼		
		½	39 22 30	½		
		¾	42 11 15	¾		
N.E.	N.W.	4	45 0 0	4	S.E.	S.W.
		¼	47 48 45	¼		
		½	50 37 30	½		
		¾	53 26 15	¾		
N.E. by E.	N.W. by W.	5	56 15 0	5	S.E. by E.	S.W. by W.
		¼	59 3 45	¼		
		½	61 52 30	½		
		¾	64 41 15	¾		
E.N.E.	W.N.W.	6	67 30 0	6	E.S.E.	W.S.W.
		¼	70 18 45	¼		
		½	73 7 30	½		
		¾	75 56 15	¾		
E. by N.	W. by N.	7	78 45 0	7	E. by S.	W. by S.
		¼	81 33 45	¼		
		½	84 22 30	½		
		¾	87 11 15	¾		
East.	West.	8	90 0 0	8	East.	West.

TABLE

Showing the length of a degree of longitude in nautical miles on any parallel of latitude from the equator to the poles, calculated on the assumption that the earth is an oblate spheroid and that a nautical mile, or knot by Admiralty regulation, is the mean length of one minute of longitude (or the sixtieth part of a degree) on the equator. Mean equatorial diameter = 41,847,662 feet, therefore equatorial circumference = 131,468,196 feet, which divided by 21,600 = (360° × 60′) or the number of minutes in a circle, gives 6,086 feet or the length of a minute of longitude on the equator.

Lat.	Length of Degree.	Lat.	Length of Degree.	Lat.	Length of Degree.
°	′	°	′	°	′
0	60·000	30	52·005	60	30·079
1	59·990	31	51·482	61	29·162
2	59·970	32	50·930	62	28·245
3	59·921	33	50·368	63	27·318
4	59·852	34	49·796	64	26·372
5	59·773	35	49·205	65	25·426
6	59·675	36	48·603	66	24·479
7	59·556	37	47·982	67	23·513
8	59.418	38	47·341	68	22·547
9	59·270	39	46·691	69	21·571
10	59·093	40	46·030	70	20·585
11	58·906	41	45·350	71	19·599
12	58·699	42	44·660	72	18·603
13	58·472	43	43·950	73	17·598
14	58·235	44	43·230	74	16·592
15	57·969	45	42·501	75	15·577
16	57·693	46	41·752	76	14·561
17	57·397	47	40·992	77	13·546
18	57·082	48	40·223	78	12·521
19	56·756	49	39·445	79	11·485
20	56·402	50	38·646	80	10·450
21	56·037	51	37·838	81	9·415
22	55·662	52	37·019	82	8·380
23	55·258	53	36·191	83	7·335
24	54·844	54	35·353	84	6·290
25	54·410	55	34·496	85	5·245
26	53·966	56	33·648	86	4·200
27	53·503	57	32·760	87	3·155
28	53·020	58	31·873	88	2·100
29	52·517	59	30·976	89	1·055

Distance of the Visible Horizon as Seen from Various Elevations.

Height in Feet.	Distance in Sea Miles.	Height in Feet.	Distance in Sea Miles.	Height in Feet.	Distance in Sea Miles.	Height in Feet.	Distance in Sea Miles.	Height in Feet.	Distance in Sea Miles.
1	1·06	51	7·59	102	10·74	360	20·18	1120	35·59
2	1·50	52	7·67	104	10·84	370	20·46	1140	35·90
3	1·84	53	7·74	106	10·95	380	20·73	1160	36·22
4	2·13	54	7·81	108	11·05	390	21·00	1180	36·54
5	2·38	55	7·89	110	11·15	400	21·27	1200	36·84
6	2·60	56	7·96	112	11·25	410	21·53	1220	37·14
7	2·81	57	8·03	114	11·35	420	21·79	1240	37·45
8	3·01	58	8·10	116	11·45	430	22·05	1260	37·75
9	3·19	59	8·17	118	11·55	440	22·31	1280	38·05
10	3·36	60	8·24	120	11·65	450	22·66	1300	38·34
11	3·53	61	8·31	122	11·75	460	22·81	1320	38·64
12	3·68	62	8·37	124	11·84	470	23·05	1340	38·93
13	3·83	63	8·44	126	11·94	480	23·30	1360	39·22
14	3·98	64	8·51	128	12·03	490	23·54	1380	39·50
15	4·12	65	8·58	130	12·12	500	23·78	1400	39·79
16	4·25	66	8·64	132	12·22	510	24·01	1420	40·07
17	4·38	67	8·70	134	12·31	520	24·25	1440	40·35
18	4·51	68	8·77	136	12·40	530	24·48	1460	40·63
19	4·53	69	8·83	138	12·49	540	24·71	1480	40·91
20	4·76	70	8·89	140	12·58	550	24·94	1500	41·19
21	4·87	71	8·96	142	12·67	560	25·16	1550	41·87
22	4·99	72	9·02	144	12·76	570	25·39	1600	42·54
23	5·10	73	9·09	146	12·85	580	25·61	1650	43·20
24	5·21	74	9·15	148	12·94	590	25·83	1700	43·85
25	5·32	75	9·21	150	13·03	600	26·05	1750	44·49
26	5·42	76	9·27	155	13·24	620	26·48	1800	45·12
27	5·52	77	9·33	160	13·45	640	26·90	1850	45·74
28	5·62	78	9·39	165	13·66	660	27·32	1900	46·35
29	5·72	79	9·45	170	13·87	680	27·73	1950	46·96
30	5·82	80	9·51	175	14·07	700	28·14	2000	47·56
31	5·92	81	9·57	180	14·27	720	28·53	2050	48·15
32	6·01	82	9·63	185	14·46	740	28·93	2100	48·73
33	6·11	83	9·69	190	14·66	760	29·32	2150	49·31
34	6·20	84	9·75	195	14·85	780	29·70	2200	49·88
35	6·29	85	9·80	200	15·04	800	30·08	2250	50·44
36	6·38	86	9·86	210	15·41	820	30·45	2300	51·00
37	6·47	87	9·92	220	15·77	840	30·82	2350	51·55
38	6·56	88	9·98	230	16·13	860	31·19	2400	52·10
39	6·64	89	10·03	240	16·47	880	31·55	2450	52·64
40	6·73	90	10·09	250	16·81	900	31·90	2500	53·17
41	6·81	91	10·14	260	17·15	920	32·25	2550	53·70
42	6·89	92	10·20	270	17·47	940	32·60	2600	54·22
43	6·97	93	10·25	280	17·79	960	32·95	2650	54·74
44	7·05	94	10·31	290	18·11	980	33·29	2700	55·25
45	7·13	95	10·36	300	18·42	1000	33·63	2750	55·76
46	7·21	96	10·42	310	18·72	1020	33·96	2800	56·27
47	7·29	97	10·47	320	19·02	1040	34·29	2850	56·77
48	7·37	98	10·53	330	19·32	1060	34·62	2900	57·27
49	7·44	99	10·58	340	19·61	1080	34·95	2950	57·76
50	7·52	100	10·63	350	19·90	1100	35·27	3000	58·25

TABLE showing whether a Steam Vessel gains or loses by keeping away a given number of Points from the True Course, thereby enabling her to set Fore and Aft Canvas for the purpose of economising fuel.

Points from the Wind.	Rate per Hour Steaming head to Wind.								
	1	2	3	4	5	6	7	8	9
	Rate per Hour a Ship must go, if she keeps away, to be in as good a position as she would have been had she held on her Course.								
1	1·02	2·04	3·06	4·08	5·10	6·12	7·14	8·16	9·17
2	1·08	2·16	3·25	4·33	5·41	6·49	7·58	8·66	9·74
3	1·20	2·40	3·61	4·81	6·00	7·21	8·42	9·60	10·82
4	1·40	2·83	4·24	5·65	7·07	8·48	9·90	11·30	12·73
5	1·80	3·60	5·40	7·20	9·00	10·80	12·60	14·40	16·20
6	2·60	5·20	7·84	10·45	13·06	15·68	18·30	20·90	23·52

Example.

A Ship is able to steam 4 knots an hour head to wind; by keeping away 4 points, and setting fore and aft sails she makes six knots an hour. The Table shows that if she made 5·65 knots, she would be in as good a position as if she remained steering head to wind, therefore if she can steam 6 knots she gains nearly half a knot an hour; but if she can only steam and sail at the rate of 5 knots, she is losing.

If the vessel keeps away 5 points she must steam or sail at the rate of 7·2 knots to be in an equally good position.

TABLE for finding the Distance of an Object by two Bearings and the Distance run between them.

DIFFERENCE BETWEEN COURSE AND FIRST BEARING.

Difference between Course and Second Bearing.	Points.	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
	4	1·00																
	4½	0·81	1·23															
	5	0·69	1·00	1·45														
	5½	0·60	0·85	1·17	1·66													
	6	0·54	0·74	1·00	1·35	1·85												
	6½	0·49	0·67	0·88	1·14	1·50	2·02											
	7	0·46	0·61	0·79	1·00	1·27	1·64	2·17										
	7½	0·43	0·57	0·72	0·90	1·11	1·39	1·77	2·30									
	8	0·41	0·53	0·67	0·82	1·00	1·22	1·50	1·87	2·41								
	8½	0·40	0·51	0·63	0·76	0·92	1·09	1·31	1·58	1·96	2·50							
	9	0·39	0·49	0·60	0·72	0·85	1·00	1·18	1·39	1·66	2·03	2·56						
	9½	0·38	0·48	0·58	0·69	0·80	0·93	1·08	1·25	1·46	1·72	2·08	2·60					
	10	0·38	0·47	0·57	0·66	0·76	0·88	1·00	1·14	1·31	1·51	1·76	2·11	2·61				
	10½	0·38	0·47	0·56	0·65	0·74	0·84	0·94	1·06	1·19	1·35	1·55	1·79	2·12	2·60			
	11	0·39	0·47	0·56	0·64	0·72	0·81	0·90	1·00	1·11	1·24	1·39	1·57	1·80	2·11	2·56		
	11½	0·40	0·48	0·56	0·63	0·71	0·79	0·87	0·95	1·05	1·15	1·27	1·41	1·58	1·79	2·08	2·50	
	12	0·41	0·49	0·57	0·64	0·71	0·78	0·85	0·92	1·00	1·08	1·18	1·29	1·41	1·57	1·76	2·03	2·41
	12½	0·43	0·51	0·58	0·65	0·71	0·77	0·83	0·90	0·97	1·03	1·11	1·20	1·29	1·41	1·55	1·72	1·96

Take the bearing of the object, and note the number of points contained between it and the ship's head. After the bearing has altered not less than 2 or 3 points, note the number of points in the same angle again. The ship is supposed to keep the same course; if not, the course made good must be employed, and the local deviation, if considerable, allowed for, as it will affect the different courses differently. To find the distance when the last bearing was taken:—Enter the Table with the first number of points at the top, and the second number of points at the side; take out the number corresponding, and multiply it by the number of miles made good by the ship; the result is the distance in miles at the time the last bearing was taken.

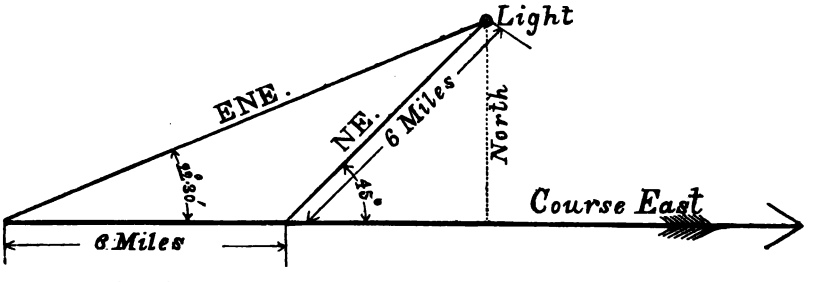
EXAMPLE.—The Eddystone bore N.W. by W; after running W. by S. 8 miles it bore N.N.E., required its distance at this last bearing. The number of points between N.W. by W. and W. by S. is 4; that between N.N.E. and W. by S. is 11; under 4 at the top and against 11 at the side stands 0·72 which multiplied by 8 (miles) gives 5·76 miles, the distance required.

RULES FOR FINDING THE DISTANCE OF A LIGHT OR OTHER OBJECT.

1.—When coming up on a light, and not wishing to leave the bridge, take a bearing of the light and note the time; also, note the number of degrees or points between the bearing and the ship's course; when this is doubled and the time again noted, the ship will be as far from the light as the distance she has made good in the interval of time between the bearings, after allowing for current, if any.

Example:—Steering East, and making 12 knots; at 8.30 p.m. a light bore E.N.E.; difference between the bearing and the ship's course equals 2 points, or 22° 30′; kept her course and stood on until the light bore N.E., or double the difference between the first bearing and the ship's course. Time, 9 p.m. ∴ elapsed time = 30 minutes = 6 miles = distance from light.

Proof—If a side of a triangle be produced, the exterior angle is equal to the two interior and opposite angles; but one interior and opposite angle is already equal to half the exterior angle, therefore the other interior and opposite angle is also equal to half the exterior angle, and things which are halves of the same thing are equal to one another, therefore the two interior and opposite angles are equal to one another, and equal sides subtend equal angles, etc. *Q. E. D.*

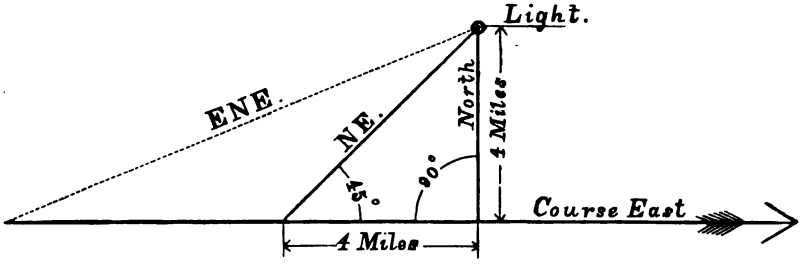


2.—Again, when coming up on a light and not wishing to leave the bridge, take note of the time when the light

shows at an angle of 45°, or 4 points from the fore-and-aft line of the vessel, as shown by the bridge compass, and again note the time when the light shows at an angle of 90°, or right abeam. The distance run in the time between the taking of the two bearings, allowance being made for current, if any, is the ship's distance from the light when the last bearing was taken.

Example :—Steering East, and making 12 knots; at 9 p.m. a light bore N.E., or 45° from the course; kept her course and stood on until the light bore North, or 90° from the course. Time, 9.20 p.m. ∴ elapsed time = 20 minutes = 4 miles = distance from light when right abeam.

Proof—Because the three interior angles of every triangle are together equal to two right angles, and the figure formed with the light being a right-angled triangle, and containing one angle of 45°, it follows that the other angle (at the light) must also be an angle of 45°; but if two angles of a triangle are equal to one another, the sides also which subtend the equal angles are equal to one another; therefore the distance made good between the two bearings, being one side of the triangle, is equal to the ship's distance from the light, which is the other side of the triangle. *Q. E. D.*



3.—In order to ascertain the ship's distance from a point of land or a light, take the bearing of the object and run with it abeam for two or three miles or more, then take its bearing again; lay both bearings off on the chart and with the parallel rulers slide the course steered up

the two bearings, until the distance run in the dividers between the times of taking the bearings agree with each bearing; one leg of the dividers will show the position of the ship when the first bearing was taken, the other leg her position at the time of last bearing.

4.—The distance from a light of known elevation can also be easily ascertained by referring to the table showing the distance of the visible horizon from various elevations. Example :—The eye of an observer is elevated 20 feet above the sea, and a light known to be elevated 155 feet has just appeared above the horizon; required the distance.

Height of eye	= 20 feet	= 4·76 miles.
Height of light	= 155 feet	= 13·24 miles.
Distance from the light		= 18 miles.

5.—Again, the distance from a lighthouse, ship, or other object of known elevation above the sea, or from some other base line, can be easily ascertained with a sextant as follows :—Multiply the height or elevation of the object in feet by ·565 and divide by the minutes of angle which it subtends, as shown on the arc of the sextant; the result will be the distance in miles. Example :—

Cape Wrath Light above high water = 400 feet × ·565 = 226

—— = 2 miles.

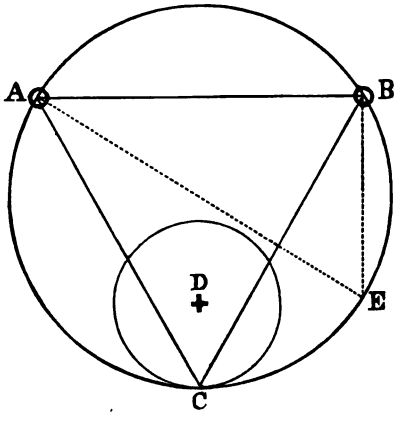
Angle at the eye of an observer = 1° 53′ × 60′ = 113

HOW TO MAKE USE OF THE DANGER ANGLE.

The danger angle can only be applied when two well defined promontories or landmarks, whose relative bearings from a known danger have been accurately determined, can be observed from the immediate vicinity of the danger.

Example :—Suppose D to represent a well known danger, covered at all states of the tide; A and B two

well defined landmarks. It is required to pass outside of the danger D at a distance of not less than half a mile. Describe a circle with a radius of half a mile about D, and in that part of its circumference most remote from A and B, take any point C; join AB, BC, CA, and about the triangle ABC describe the circle ABEC. The angle ACB is equal to the angle AEB, or to any other angle in the same segment, and is consequently the angle which if placed on a sextant and kept on, will keep the ship on some part of the circumference of the circle ABEC. Should the angle shown on the sextant increase beyond what it ought to be by the chart, the ship will be inside the circle of danger, and *vice versâ*.



DIURNAL RISE AND FALL OF THE TIDES.

The alternate rise and fall of the tide is due to the attractive influences of the sun and moon, which draw or lift up the waters of the ocean toward themselves. Since the force of gravity increases as the square of the distance diminishes, it is evident that the waters on the part of the earth which is nearest the moon will feel in a greater degree the power of her attraction, and be raised accordingly; while those waters further removed from her

influence will be less raised : but as the force of attraction acts in straight lines, the waters on the part of the earth which is most remote from the moon will be raised as well as those immediately facing her—hence the spheroidal form assumed by the ocean. Again, if a line be drawn from the centre of the moon through the centre of the earth, the two points where it cuts the spheroid will be those of high water; and all points equally distant or 90 degrees from each will be those of low water, according to the progress of the tide-wave. Although the sun is so much larger than the moon, the latter on account of her nearness to the earth has the most powerful effect upon the tides, her influence being nearly three times as great as that of the sun.

It is when the sun and moon unite their influences, which they do at new and full moon, that the tides rise highest, and are called SPRING-TIDES. When the moon is in her quarters, her action is directly opposed to that of the sun and consequently the tides are then lowest, and are called NEAP-TIDES. As the moon crosses the meridian of a place every 24 hours, 50 minutes, 30 seconds, the sea in that space of time ebbs twice and flows twice all over the world; therefore, in the open sea the tide requires nearly six hours and a quarter to rise from low water to high water, and the same time to fall from high to low water.

The Range of the tide is the difference between the levels of high and low water. The rise or fall of the tide per hour assumes very nearly the following proportions—

In the first hour about $\frac{1}{12}$ of the range.
In the second hour about $\frac{3}{12}$ of the range.
In the third hour about $\frac{4}{12}$ of the range.
In the fourth hour about $\frac{4}{12}$ of the range.
In the fifth hour about $\frac{3}{12}$ of the range.
In the sixth hour about $\frac{1}{12}$ of the range.

Thus, at about two hours from low water, the tide has risen one-fourth of its range; at three hours, or half tide, it has risen one-half of its range; and at four hours, it has risen three-fourths of its range. Now, as any of the above quantities taken from a sounding will only reduce it to the low water of the tide for that day (which may happen to be a neap-tide, while the depths marked on the chart are given for low water at ordinary springs), it becomes necessary to apply a further correction before a cast of the lead taken at any state of the tide on any day besides *full* and *change* will admit of direct comparison with the depths marked on the chart. This correction is extremely simple, and easy of application, and only necessitates the use of the Admiralty Tide Tables, which contain the requisite data and examples for the reduction of soundings under all circumstances.

HOW TO FIND THE TIME OF HIGH WATER.

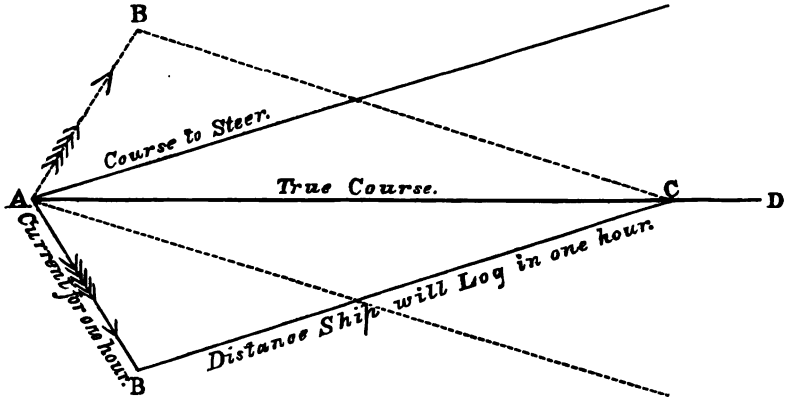
The Tide Tables for the British and Irish Ports, published by order of the Lords Commissioners of the Admiralty, contain the morning and afternoon tides for twenty-four of the principal home ports, and tidal constants for various British, Irish, and European ports, which, being applied according to the sign + or − to the times or heights belonging to the standard port to which each of them is referred, will afford a ready means of determining approximately the height as well as the time of high water at each of those several places; in addition to which they have the time of high water on *full* and *change* days at the principal places on the globe, arranged according to the apparent progress of the tide-wave, as well as alphabetically, with the rise of the tide at springs and neaps. When the above tide tables are not at hand, nor any other tables available, the time of high water can

be found approximately by either of the two following methods.

I. To the time of high water at *full* and *change*, as given in the Sailing Directions and Nautical Almanac, or shown by Roman numerals on the chart, add 49 minutes for every day that has elapsed since *full* and *change*, the sum being the P.M. tide for the given day.

II. To the time of high water at *full* and *change* add the time of the Moon's Meridian Passage corrected for longitude (see page IV. of each month in the Nautical Almanac and corresponding Explanation), the sum being the P.M. tide for the given day.

HOW TO ALLOW FOR THE SET AND DRIFT OF A CURRENT.

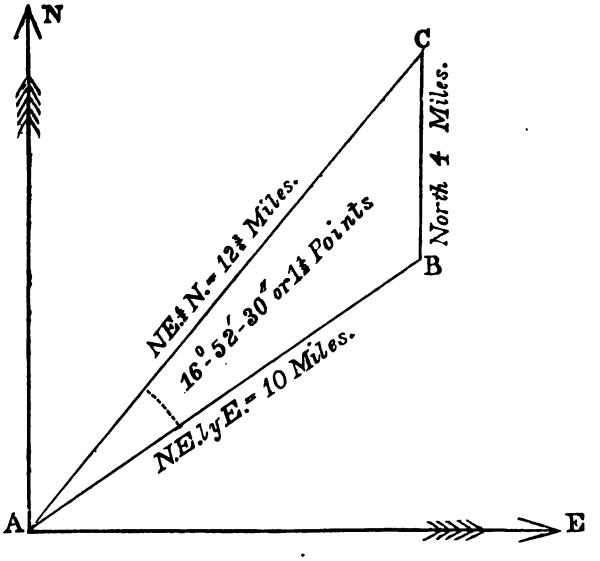


Let A represent the ship's place on the chart and D her destination, join AD, then the line AD is the course required to be made good. From A draw a line AB in the direction in which the current sets and equal to the distance it runs in one hour, then take in the dividers the distance the ship will log in one hour, and place one leg of the dividers at B, letting the other leg take the

true course AD at any point C, join BC. The direction of the line BC taken to the nearest compass on the chart is the course to steer from A in order to counteract the current AB, and make good the true course AD.

The dotted lines in the figure represent an imaginary current setting in another direction from the point A, and the course to counteract it.

Again, to determine the effect of the tide upon a ship's course, suppose a ship steers a N.E. by E. course, steaming at the rate of 10 knots an hour, or from A to B, and suppose the tide to run North 4 miles an hour, or from B to C, by laying off these as two separate courses, it will be seen that the course made good is from A to C, or N.E. $\frac{1}{2}$ N. $12\frac{3}{4}$ miles.



By the Traverse Table as follows :—

	Diff. Lat.	Dep.
Course 56° 15′ E., distance 10 miles	= 5·6 N.	—8·3 E.
Tide north, distance 4 miles	= 4·0 N.	—0·0
Course made good N.41°E.$12\frac{3}{4}$ miles	= 9·6 N.	—8·3 E.

Again, when shaping a course through a tide the operation is reversed, thus in the above figure if the course to be sailed had been N.E. ½ N., the allowance of 1½ points to the right for the tide would make the course to be steered N.E. by E.

If the tide is marked 3 knots on the chart at *springs* at the 1st hour, 2nd hour, 3rd hour, 4th hour, 5th hour, take 1 knot, 2 knots, 3 knots, 2 knots, 1 knot.

If it be *neap* tides take one-third from each of these quantities.

As a rough general rule, a vessel in the fairway of the Channel will be carried at *springs*, in one whole tide, about 9 miles, and at *neaps* about 6 miles; but nearer the land, on either side, the rates will increase.

SIR WILLIAM THOMSON'S SOUNDING MACHINE.

This machine is designed for the purpose of ascertaining accurately and quickly the depth of water under a ship without stopping or even reducing her speed.

The apparatus consists of a light wheel, on which is coiled about 300 fathoms of pianoforte steel wire. The stand to which the supports of the wheel are attached is fixed to the taffrail, at the stern of the vessel, so that the sinker can be left hanging ready for a cast. A cord wound round a groove in the circumference of the drum is so arranged as to form a self-acting brake, which, when the sinker is hanging, offers enough of resistance to prevent it from running down, but, when it is being hauled in, offers very little resistance to the turning of the wheel. When a sounding is being taken the brake is released by the hand, so as to leave a force of about 7 lbs. pulling on the rope, by which a resistance of about 5 lbs. is opposed to the wire while it is running out. Thus, when the sinker reaches the bottom the wheel suddenly stops;

the brake is then applied to prevent the wire from running out again.

The sinker is a long iron weight of 22 lbs., with a hollow at the lower end to receive the usual arming of tallow for getting a specimen of the bottom. It is attached to the end of the wire by a rope six or eight feet in length.

A brass tube rather more than two feet in length is secured to the rope connecting the sinker with the wire. A glass tube, two feet long, coated inside with a preparation of chromate of silver, and closed at one end and open at the other, is placed (with its open end down) in the brass tube. As the sinker descends, the increased pressure drives the sea-water up the glass tube, which, combining with the chromate of silver, makes a white mark. The height of the white mark registers the height to which the water has been forced up the tube. A scale graduated to fathoms shows at once the depth to which the glass tube has been. This method of taking soundings depends on the increased pressure as the tube descends, but is independent of the amount of line out, so that the vessel does not require to be stopped to take a sounding.

The advantages of wire as compared with rope are the smallness of area and smoothness of surface, so that it offers very little resistance. This allows the sinker to descend very quickly, and to be hauled on board again with great ease, so that two men working the machine can take soundings in 100 fathoms every few minutes from a ship running at any speed up to 16 or 17 knots.

LEADS AND LEAD-LINES.

The hand-lead weighs from 7 to 14 lbs., and is usually hove forward from the main channels, the soundings being taken as the ship passes the spot where the lead entered the water.

The hand-line is from 25 to 30 fathoms long.

The deep-sea lead weighs from 28 to 35 lbs., and is usually hove from the weather cathead, the line having been passed forward outside of everything from the weather quarter where the soundings are taken as the ship forges ahead.

The deep-sea line is from 100 to 150 fathoms long.

The hollow in the lead is armed with tallow for the purpose of ascertaining the nature of the bottom.

The Marks on the line are given below, the intermediate soundings being called Deeps.

Fathoms.			
2	...	...	Leather, with 2 strips.
3	...	...	Leather, with 3 strips.
5	...	...	White Bunting.
7	...	...	Red Bunting.
10	...	...	Leather, with round hole.
13	...	...	Blue Bunting.
15	...	...	White Bunting.
17	...	...	Red Bunting.
20	...	...	2 Knots.
25	...	...	1 Knot.
30	...	...	3 Knots.
35	...	...	1 Knot.
40	...	...	4 Knots, and so on.

LOG LINES AND GLASSES.

With the common log-ship there should be about 10 fathoms of stray line for a sailing vessel, and say 20 fathoms for a steam vessel, to allow the log to get clear of the eddy in the wake of the ship. The stray line is terminated with a piece of white bunting, after which the line is marked at equal distances with—

One knot to represent every half knot.
Piece of leather to represent one knot.
Two knots to represent two knots.
Three knots to represent three knots.
Four knots to represent four knots, and so on.

The length of each knot must be in the same proportion to a sea mile or knot, as the sand glass is to an hour.

The long glass runs for 28 seconds, and is used when the ship is going slowly through the water.

The short glass runs for 14 seconds, and is used when the ship is going fast through the water. With this glass the speed shown on the line must be doubled if the line is marked for a 28-second glass. The glass should be occasionally checked by comparison with a seconds watch, and the line re-marked if necessary.

To calculate the length of a knot for any glass, say for one running 28 seconds,

as 1h. : 28s. :: 1 mile : length of line for one knot

3600s. : 28s. :: 6086 ft. : length of line for one knot

$$\frac{28 \times 6086}{3600} = 47{\cdot}335 = \text{say 47 feet to a knot.}$$

For a glass running 14 seconds half the above length would be taken, viz., 23 feet 6 inches. It is always advisable to keep the length of the knots rather to the

short side, in order to avoid the risk of letting the ship over-run her reckoning.

Massey's Frictionless Log is one of the most reliable self-indicating instruments for ascertaining the distance run in a given time. It is towed from the weather counter, and sometimes from an outrigger 8 or 10 feet in length, to keep the log clear of the eddy in wake of the ship, with from 30 to 60 fathoms of patent line.

Walker's Taffrail Log is a most complete instrument, and saves a great amount of labour.

Lee-way can always be ascertained before hauling in the log by having a graduated arc on the taffrail and a small crutch or fairlead fixed inboard at a distance corresponding to the radius of the arc. The angle which the log-line (when placed in the crutch) makes with the fore-and-aft line of the vessel is the lee-way.

COMMON LOGARITHMS.

Logarithms were invented by John Napier, Baron of Merchiston. They are a series of numbers in arithmetical progression corresponding to another series of numbers in geometrical progression, and are used in order to facilitate processes of numerical calculation.

EXAMPLES.

Base 10	Nos.	=1	10	100	1,000	10,000	100,000	1,000,000	10,000,000	
	Logs.	=0	1	2	3	4	5	6	7	
Base 5	Nos.	=1	5	25	125	625	3,125	15,625	78,125	390,625
	Logs.	=0	1	2	3	4	5	6	7	8

To *Multiply—add* the logarithms of the numbers together, and find the number to correspond.

To *Divide—subtract* the logarithms of the numbers from one another, and find the number to correspond.

Involution, or raising a number to any power,—*multiply* the logarithm of the number by the index or power required.

Evolution, or extracting the root of a number,—*divide* the logarithm of the number by the index of the root.

Every logarithm consists of two parts, the *index* and the decimal part or *mantissa*.

The index or log proper is supplied by the calculator, and is always one less than the number of integral figures in the number.

When the number has no integral figures, the index of the logarithm is one more than the number of cyphers immediately after the decimal place, and has the negative sign (—) placed over it.

Examples of indices supplied to numbers giving the same Log.

Number.	Index. Logarithm.
2468·	3·392345
246·8	2·392345
24·68	1·392345
2·468	0·392345
·2468	$\bar{1}$·392345
·02468	$\bar{2}$·392345
·002468	$\bar{3}$·392345

LOGARITHMS.

Multiplication.

Minor Corrections. Log.	Diff.	
		Multiply 26100 Log 4·416640 By ·00472 Log $\bar{3}$·673942 Log 2·090582 Answer = 123·2
928959 41 929000	51 8 40·8	Multiply 849·18 Log 2·929000 By ·08382 Log $\bar{2}$·923348 Log 1·852348 Answer = 71·18
809021 47 809068 301898 50 301948	67 7 46·9 217 23 651 434 49·91	Multiply 64·427 Log 1·809068 By 200·423 Log 2·301948 Log 4·111016 ·110926 Diff. = 335)900(27 nearly 670 2300 2345 Answer = 12912·7

Division.

Change the sign of the lower and *add* instead of subtracting, thus—	
$\bar{2} = -2$ $\bar{3} = +3$ $1 = +1$	Divide ·01927 Log $\bar{2}$·284882 By ·00134 Log $\bar{3}$·127105 Log 1·157777 Answer = 14·38
439333 73 439406 144263 183 144446	158 46 948 632 72·68 311 59 2799 1555 183·49
	Divide 27·5046 Log 1·439406 By 139·459 Log 2·144446 Log $\bar{1}$·294960 Answer = ·1972

Involution.

Required the square or second power of 99

Number 99	... ...	Log 1·995635
Index, or power	... ...	2
		Log 3·991270

Answer = 9801

Required the square or second power of ·185

Number ·185	... ...	Log $\bar{1}$·267172
Index, or power	... ...	2
		Log $\bar{2}$·534344

Answer = ·03422

Required the cube or third power of 4·5

Number 4·5	... ...	Log 0·653213
Index or power	... ...	3
		Log 1·959639

Answer = 91·13

Evolution.

Required the square root of 9801

Number 9801	...	Log 2)3·991270
		Log 1·995635

Answer = 99

Required the square root of ·03422

Number ·03422	...	Log 2)$\bar{2}$·534280
		Log $\bar{1}$·267140

Answer = ·185

Required the cube root of 91·13

Number 91·13	...	Log 3)1·959661
		Log 0·653220

Answer = 4·5

TRAVERSE SAILING, or DEAD RECKONING.

Minor Corrections.	Hours.	Courses.	Knots.	10ths	Winds.	Lee-way.	Devia-tion.	Remarks.
° ′	1		5	0				
	2		5	6				
N. 56 15 W.	3	West	6	4	S. ½ W.	1½	25° E.	A point of land in lat. 14° 12′ S. long. 179° 38′ W. bearing by compass S.E. by E. dist. 38 miles. Deviation 4° W. Variation 9° 25′ E. Current set by compass W. ½ S. = 33 miles from the time departure was taken to the end of the day.
4 0 W.	4		6	0				
N. 60 15 W.	5		7	0				
9 25 E.	6	W.N.W.	6	0	N. by E.	1½	24° E.	
N. 50 50 W.	7		6	1				
	8		6	9				
N. 73 7 W.	9		7	0				
25 0 E.	10		8	9				
N. 48 7 W.	11	S.W.	8	1	N.W. by W.	1	17° E.	
9 25 E.	12		8	0				
N. 38 42 W.	1		7	0				
	2		6	1				
N. 81 34 W.	3	S.S.W.	7	9	N.W. by W.	⅔	8° E.	
24 0 E.	4		6	0				
N. 57 34 W.	5		6	0				
9 25 E.	6		6	0				
N. 48 9 W.	7	S.S.E.	6	0	W. ⅔ N.	½	17° W.	
	8		6	0				
S. 33 45 W.	9		5	0				
17 0 E.	10		5	0				
S. 50 45 W.	11	W. ⅔ S.	5	0	N. by E.	¼	24° E.	
9 25 E.	12		5	0				
S. 60 10 W.								

Correct the courses for deviation, variation, and leeway, and find the course and distance from the given point, and the latitude and longitude in by inspection.

Corrected courses.	Dist.	Diff. Lat. N.	Diff. Lat. S.	Dep. E.	Dep. W.
N. 51 W.	38	23·9	.....	.....	29·5
N. 39 W.	23	17·9	.....	.....	14·5
N. 48 W.	26	17·4	.....	.....	19·3
S. 60 W.	32	.....	16·0	.....	27·7
S. 31 W.	27	.....	23·1	.....	13·9
S. 36 E.	24	.....	19·4	14·1	.....
N. 68 W.	20	7·5	.....	.....	18·5
N. 86 W.	33	2·3	.....	.....	32·9
		69·0	58·5	14·1	156·3
		58·5			14·1
		10·5 = Diff. Lat.			142·2 = Dep

Lat. left, ... 14° 12′ 00″ S. Long. left, ... 179° 38′ W.
Diff. Lat. ... 10 30 N. Diff. Long. ... 2 27 W.
Lat. in = 14 1 30 S. Long. in = 182 5 W.
2) 8 13 30 or from 360
Mid Lat. = 14 6 45 Long. in = 177 55 E.

Course N. 86° W. and distance 143 miles.

S. 14 4 W.
8 0 E.
S. 22 4 W.
9 25 E.
S. 31 29 W.
S. 28 8 E.
17 0 W.
S. 45 8 E.
9 25 E.
S. 35 43 E.
S. 78 45 W.
24 0 E.
S. 102 45 W.
180
N. 77 15 W.
9 25 E.
N. 67 50 W.
S. 84 22 W.
9 25 E.
S. 93 47 W.
180
N. 86 13 W.

Look for middle latitude as a course, and for departure in a latitude column, then the distance will equal the difference of longitude.

Look for difference of latitude and departure to come together, then distance to correspond is distance made good, and course is taken from top or bottom of page to suit.

PARALLEL SAILING.

In latitude 39° 55′ the departure made good was 482 miles, required the difference of longitude by parallel sailing.

Latitude 39° 55′	Sec 0·115217
Departure 482	Log 2·683047
	Log 2·798264

Diff. Long. = 628·4 miles.

In latitude 62° 51′ the departure made good was 173·3 miles, required the difference of longitude by parallel sailing.

Latitude 62° 51′	Sec 0·340729
Departure 173·3	Log 2·238799
	Log 2·579528

Diff. Long. = 379·8 miles.

In latitude 35° 45′ the departure made good was 382 miles, required the difference of longitude by parallel sailing.

Latitude 35° 45′	Sec 0·090672
Departure 382	Log 2·582063
	Log 2·672735

Diff. Long. = 470·7 miles.

In latitude 62° 55′ the departure made good was 212 miles, required the difference of longitude by parallel sailing.

Latitude 62° 55′	Sec 0·341716
Departure 212	Log 2·326336
	Log 2·668052

Diff. Long. = 465·6 miles.

MERCATOR'S SAILING.

Required the course and distance from lat. 26° 43′ S. and long. 149° 50′ W. to lat. 20° 16′ N. and long. 175° 15′ E.

Lat. 26° 43′ S. Mer. pts. 1664 Long. 149° 50′ W.
Lat. 20° 16′ N. Mer. pts. 1242 Long. 175° 15′ E.

46 59 M. D. Lat. = 2906 — 325 5 E.
60 — 360
Pro. Diff. Lat. = 2819 miles. — 34 55 W.
60
Diff. Long. = 2095 miles.

Diff. Long. 2095 Log 13·321184 = (always *add* radius 10).
M. D. Lat. 2906 Log 3·463296
Course = 35° 47′ Tang. 9·857888

Course 35° 47′ Sec 0·090854
P. D. Lat. 2819 Log 3·450095
Distance = 3475 Log 3·540949

Course N. 35° 47′ W.—Distance 3475 miles.

Required the course and distance from *Callao* to *Port Otago*, by calculation on Mercator's principle.

Lat. of Callao = 12° 4′ S. Long 77° 6′ W.
Lat. of Port Otago = 45° 46′ S. Long, 170° 37′ E.

Lat. 45° 46′ S. Mer. pts. 3095 Long. 170° 37′ W.
Lat. 12° 4′ S. Mer. pts. 729 Long. 77° 6′ E.

33 42 M. D. Lat. = 2366 — 247 43
60 — 360
Pro. Diff. Lat. = 2022 miles. — 112 17
60
Diff. Long. = 6737 miles.

Diff. Long. 6737 Log 13·828467 = (always *add* radius 10).
M. D. Lat. 2366 Log 3·374015
Course = 70° 39′ Tang. 10·454452

Course 70° 39′ Sec 0·479729
P. D. Lat. 2022 Log 3·305781
Distance = 6103 Log 3·785510

Course S. 70° 39′ W.—Distance 6103 miles.

GREAT CIRCLE SAILING.

In Parallel and Mercator's sailings a ship approaches her destination by a circuitous route, while in Great Circle sailing every mile she makes good is a direct advance towards her destination.

The distance between any two points on the surface of a sphere is always measured on an arc of a great circle, and as this arc or curve always approaches nearer to the pole than any other arc or curve of conjunction, it necessarily becomes the shortest distance between any two points, for, as the number of miles on any parallel of latitude decreases as the distance from the equator increases, so the distance between any two points on the surface of a sphere becomes less as the apex of the curve of the great circle which passes through them approaches either of the poles. This is especially the case when both points are situated in the same hemisphere, and have a considerable difference of longitude.

Now, as the calculations for determining the successive courses to be followed when attempting to delineate a great circle track upon a chart are somewhat troublesome, and, for many reasons, it is impracticable to keep a ship always on an exact great circle track, it follows that a more approximate and expeditious method of determining the great circle course becomes all that is necessary. The simplest and most comprehensive way of finding the necessary elements for sailing on a great circle is to have a terrestrial globe arranged so that any two places can be brought down together to the edge of the circular frame or horizon, inside of which the globe revolves, and then by using the frame as a ruler and tracing a light line with a fine pencil between the two places, there remains a great circle track laid off on the globe ready for reference and showing not only the latitude and longitude of the apex, but the latitudes at which the track intersects the meridi-

ans lying between the two places. The corresponding courses are found by measuring with a protractor or horn semicircle the angles contained between the track and the successive meridians, the distance between the two places being measured on the equator or horizon of the globe.

The method devised by Sir G. B. Airy, Astronomer Royal, for sweeping an arc of a circle on one side of the equator on Mercator's charts, approaches very near to the correct projection of a great circle, and, while accurate in principle, is also easy of application. Rule:—Join the two points, between which it is required to project the great circle, by a straight line. Bisect this line, and from the point of section erect a perpendicular to the line on the side next the equator, continuing it if necessary beyond the equator. With the middle latitude between the two places enter the following table, and take out the "corresponding parallel." The centre of the arc of the great circle, required to be drawn, will be the intersection of this parallel with the perpendicular.

Middle Latitude.		Corresponding Parallel.	Middle Latitude.		Corresponding Parallel.
20°	Opposite name to latitude of points.	81° „ 13′	58°	Same name as lat. of points.	4° „ 0′
22		78 „ 16	60		9 „ 15
24		74 „ 59	62		14 „ 32
26		71 „ 26	64		19 „ 50
28		67 „ 38	66		25 „ 9
30		63 „ 37	68		30 „ 30
32		59 „ 25	70		35 „ 52
34		55 „ 5	72		41 „ 14
36		50 „ 36	74		46 „ 37
38		46 „ 0	76		52 „ 1
40		41 „ 18	78		57 „ 25
42		36 „ 31	80		62 „ 51
44		31 „ 38			
46		26 „ 42			
48		21 „ 42			
50		16 „ 39			
52		11 „ 33			
54		6 „ 24			
56		1 „ 13			

ROUND THE WORLD SAILING.

In sailing from England in an easterly direction round the world, one entire day (24 hours) is *gained* by daily putting the watch forward according to the easting made, for the ship is sailing against the sun.

On arriving, say, on Saturday the 14th at 180° East longitude, 12 hours have been gained, and in order to avoid being 24 hours ahead of Greenwich time on the ship's arrival in England, the following day, which would otherwise have been Sunday the 15th, must instead be called Saturday the 14th—that is, two Saturdays.

In sailing from England in a westerly direction round the world, one entire day (24 hours) is *lost* by daily putting the watch back according to the westing made, for the ship is sailing with the sun.

On arriving, say, on Saturday the 14th at 180° West longitude, 12 hours have been lost, and in order to avoid being 24 hours behind Greenwich time on the ship's arrival in England, the following day, which would otherwise have been Sunday the 15th, must instead be called Monday the 16th—that is, no Sunday.

In other words, the difference of longitude from any given meridian has a corresponding difference of time in the proportion of 1 second of time to 15 seconds of longitude; 4 seconds = 1′, 1 minute = 15′, 4 minutes = 1°, 1 hour = 15°, and so on. Thus, at any given moment, the mean solar time at two stations on the earth's surface differs by an amount proportional to their difference of longitude, the time at the eastern station being the later of the two.

At two adjacent stations placed one on either side of the 180th meridian there is therefore a difference of 24 hours, or one entire day, between their mean solar dates corresponding to the given moment, the date at the station to the westward of the 180th meridian being the later of the two.

MEASUREMENTS OF TIME.

The Earth performs every revolution on its axis in precisely the same period of time; consequently, if the heavenly bodies always retained the same positions relative to one another, the interval of time between the departure and return of a terrestrial meridian to each body in succession would be the same, and all days of equal length; but owing to the varying velocities of the different bodies, the days as computed from observations of each body are periods of unequal and variable duration: thus—

The interval of time between the departure and return of any meridian to the Sun, Moon, or a Star, is denominated a *solar*, *lunar* or *sidereal* day, according to the name of the body whose consecutive transits are observed.

The interval of time between the departure and return of any meridian to the *sun* is called an *apparent solar day;* it is a period of unequal duration, therefore, with a view of obtaining a convenient and uniform measure of time, astronomers have recourse to what is termed a *mean solar day*, whose length is equal to the average of all the apparent solar days in the year. An imaginary sun, called the *mean* sun, is supposed to move uniformly in the Equinoctial with the real sun's mean motion in Right Ascension, and the interval of time between the departure and return of any meridian to the *mean* sun is the duration of a *mean solar day.*

Chronometers are adjusted to mean solar time, so that two complete revolutions of the hour hand should be performed in exactly the same time as a revolution of the earth on its axis with respect to the mean sun.

The time deduced from observation of the *true* sun is called *true* or *apparent* time; the time deduced from the *mean* sun, as indicated by the chronometer, which represents its motion, is called *mean* time. The difference between apparent and mean time, or the angular distance

in time between the true and mean sun, is called the Equation of Time, and serves for the conversion of either time into the other by *adding* or *subtracting* according to the directions at the head of Equation of Time columns in the Nautical Almanac.

Mean time although not obtainable by observation alone, may be readily deduced from observation of the true sun by aid of the Equation of Time; thus, when the true sun was observed on the meridian of Greenwich on Jan. 1st, 1880, it would be apparent noon on that meridian, and the Equation of Time at that instant would be 3m. 37·78s. *to be added to apparent time;* hence the corresponding mean time would be, Jan. 1d. 0h. 3m. 37·78s., showing that the mean sun had crossed the meridian previous to the true sun.

Before using the Nautical Almanac it becomes necessary to ascertain the Greenwich time corresponding to any given time on the meridian of an observer—this is the difference between the two meridians, or longitude turned into time, *added to* or *subtracted from* the given time according as the position of the observer is West or East of Greenwich.

Rule:—Multiply the longitude by 4 and divide by 60, then *add* the astronomical time at position of observer if in West; *subtract*, if in East longitude: the result will be corresponding Greenwich time. All *civil* reckoning must also be converted into corresponding *astronomical* time by the following simple rule, viz.:—In civil time for P.M. make no change, for A.M. diminish the days of the month by 1 and add 12 to the hours. Thus—

Jan. 2nd, 7h. 49m. P.M. = Jan. 2nd, 7h. 49m. astronomical.
Jan. 2nd, 7h. 49m. A.M. = Jan. 1st, 19h. 49m. astronomical.

USE OF MERCATOR'S CHART.

On Mercator's chart all the meridians are parallel, and the degrees of longitude are equal. The degrees of latitude are unequal, being extended at each degree in the same proportion as the degrees of longitude on a globe are diminished, consequently the degree of latitude increases in length as the latitude increases; therefore, in measuring the distance between any two places on this projection, observe the following directions:—

1. When the places are on the same meridian, their Diff. Lat., as shown on the graduated meridian at the side of the chart is the distance required.

2. When the places are on different meridians, the half distance between them is taken with a pair of dividers; then, placing one leg of the dividers on the graduated meridian corresponding to the latitude of the half distance, and measuring on each side of it, the number of miles or Diff. Lat. included between these two extreme points will be the distance required.

ADJUSTMENTS OF THE SEXTANT.

The first adjustment of the sextant is to set the index glass perpendicular to the plane of the instrument; it is made thus:—Place the index near the middle of the arc and hold the sextant horizontally with its face upwards, then by looking into the index glass, if the arc and its reflection are seen to be in one line, the glass is perpendicular; if not, it is made so by adjusting the screw at the back of the frame which holds the glass. This correction is only for quadrants or common sextants, for in the best instruments the index glass is fixed, and consequently requires no adjustment.

The second adjustment of the sextant is to set the horizon glass perpendicular to the plane of the instrument;

it is made thus :—Place the index at zero on the arc, and hold the sextant vertically (or horizontally when an upright object, such as a mast, is substituted for the horizon), then by looking through the horizon glass, if the true and reflected horizons are seen to be in one line, the glass is perpendicular ; if not, it is made so by adjusting a screw underneath the frame which holds the glass.

The third adjustment of the sextant is to set the horizon glass parallel to the index glass when the index is at zero ; it is made thus :—Place the index at zero on the arc and hold the sextant vertically, then by looking through the horizon glass, if the true and reflected horizons are seen to be in one line, the glass is perpendicular; if not, it is made so by adjusting a screw or screws at the back of the frame which holds the glass.

The index error can be discovered thus :—Place the index at zero on the arc and hold the sextant vertically, then by looking through the horizon glass at the horizon, if the true and reflected horizons are seen to be in one line there is no error; if not in one line, turn the tangent screw until they are; the reading is the index error. When the reading is off the arc, it is to be added, and when on the arc to be subtracted.

The index error can also be found by the sun, thus :—Place the index about 40′ on the arc, and bring the upper and lower limbs of the true and reflected suns in exact contact, read off and mark it down ; then place the index about 40′ off the arc and bring the suns in contact as before, read off and mark it down ; subtract the less from the greater reading and divide by 2, the result is the index error.

When the greater reading is off the arc it is to be added, and when on the arc to be subtracted. If the two readings are added together and their sum divided by 4, the result should correspond with the semi-diameter of the sun for the day, taken from the Nautical Almanac.

LATITUDE BY MERIDIAN ALTITUDE OF A STAR.

1880—July 21st, observed meridian altitude of "Regulus" (α Leonis) bearing South 62° 46′ 16″, index error + 3′ 13″, height of eye 15 feet. Required the Latitude :—

	°	′	″	
Observed altitude,	62	46	16	S.
Index error,	+	3	13	
	62	49	29	
Dip for 15 feet,	—	3	42	
	62	45	47	
Refraction,	—	0	29	
True altitude,	62	45	18	S.
	90			
Zenith distance,	27	14	42	N.
Declination,	12	33	2	N.
Latitude,	39	47	44	N.

1880—August 18th, observed meridian altitude of "Betelguese" (α Orionis) bearing North 65° 12′ 45″, index error—1′ 18″, height of eye 17 feet. Required the Latitude : —

	°	′	″	
Observed altitude,	65	12	45	N.
Index error,	—	1	18	
	65	11	27	
Dip for 17 feet,	—	3	57	
	65	7	30	
Refraction,	—	0	26	
True altitude,	65	7	4	N.
	90			
Zenith distance,	24	52	56	S.
Declination,	7	23	5	N.
Latitude,	17	29	51	S.

NOTE.—No correction required for Parallax or Semi-diameter. Use column of Right Ascension in Table 63 Raper or 13 Norie as an index to the Declination in the Nautical Almanac. Always *subtract* True altitude from 90° to get Zenith distance, and give it opposite name to bearing of the object. When Zenith distance and Declination are of same name *add* for Latitude ; when of contrary names *subtract*, and call Latitude same name as the greater.

LATITUDE BY MERIDIAN ALTITUDE OF THE SUN.

1880—June 20th, in longitude 148° 15′ West, observed meridian altitude ⊙ 82° 45′ 0″ bearing South, height of eye 14 feet. Required the Latitude :—

Long. 148° 15′ W.		D.	H.	M.	S.		°	′	″
4	A. T. S., June	20	0	0	0	Observed alt.,	82	45	0 S.
60)593 0	Long. in time,	+	9	53	0	Dip,	—	3	36
9 53 0	A.T. Gh., June,	20	9	53	0		82	41	24
						Refraction,	—	0	7
		°	′	″			82	41	17
Var. = 0″·58	Declination,	23	27	14	N.	Parallax,	+	0	1
9·9	Increasing,	+	0	6	N.		82	41	18
522	Correct decn.,	23	27	20	N.	S.-diameter,	+	15	46
522						True altitude,	82	57	4 S.
60)5·742							90		
0 6						Zenith dist.,	7	2	56 N.
						Correct decn.,	23	27	20 N.
S.-diar. = 15′ 46″						Latitude,	30	30	16 N.

1880—March 20th, in longitude 78° 55′ East, observed meridian altitude ⊙ 82° 19′ 30″ bearing North, height of eye 16 feet. Required the Latitude :—

Long. 78° 55′ E.		D.	H.	M.	S.		°	′	″
4	A. T. S., March	20	0	0	0	Observed alt.,	82	19	30 N.
60)315 40	Long. in time,	—	5	15	40	Dip,	—	3	50
5 15 40	A.T. Gh., March	19	18	44	20		82	15	40
						Refraction,	—	0	8
		°	′	″			82	15	32
Var. = 59″·25	Declination,	0	16	53	S.	Parallax,	+	0	2
18·7	Decreasing,	—	18	28	N.		82	15	34
41475	Correct decn.,	0	1	35	N.	S.-diameter,	+	16	5
47400						True altitude,	82	31	39 N.
5925							90		
60)1107·975						Zenith dist.,	7	28	21 S.
18 28						Correct decn.,	0	1	35 N.
S.-diar. = 16′ 5″						Latitude,	7	26	46 S.

NOTE.—Always *subtract* Dip and Refraction, *add* Parallax and Semi-diameter, unless for an altitude of the ⊙, when the Semi-diameter must be subtracted. To correct the Declination multiply *var. in* 1 *hour* by the *hours* and *minutes* of apparent time at Greenwich (turned into decimals by dividing the minutes by 6), then divide by 60 and the result is *added to* or *subtracted from* the Declination according as it is *increasing* or *decreasing*.

LATITUDE BY REDUCTION TO THE MERIDIAN.

1880—September 23rd at ship, latitude by account 39° 22′ N, longitude 117° 45′ W, observed altitude ⊙ near the meridian of observer 48° 53′ 0″, height of eye 16 feet. Time by watch or chronometer 8h. 17m. 49s. which had been found to be 7h. 32m. 15s. fast of apparent time at ship. Difference of longitude made to the Eastward 18½ miles after error on apparent time at ship was determined. Required the latitude :—

Long. made 18′·5 E.
4
60)74·0
1 14

Long. in 117° 45′ W.
4
60)471 0
7 51 0

″
Var. = 58·5
8·6
3510
4680
60)503·10
8 23

S.-diar. = 15′ 59″

	D.	H.	M.	S.		D.	H.	M.	S.		°	′	″	
Time	23	8	17	49	A.T.S.	23	0	46	48	Decn.	0	19	16	S.
Fast	—	7	32	15	Long.	+	7	51	0	Incrs.	+	8	23	S.
Time	23	0	45	34	A.T. Gh.	23	8	37	48	Cor.decn.	0	27	39	S.
Diff. long.	+	1	14											
A.T.S.	23	0	46	48										

	°	′	″		M.	S.		
Obs. alt.	48	53	0	Time fr. noon	46	48	Rising	3·31758
Dip	—	3	50	Lat. by acct.	39°	22′	Cosine	9·88824
	48	49	10	Cor. decn.	0°	28′	Cosine	9·99999
Refr.	—	0	49	Natural number		1606	= Log	3·20581
	48	48	21					
Parl.	+	0	6					
	48	48	27					
S.-diar.	+	15	59	Natural number		1606		
True alt.	49	4	26	= Natural sine		75547		
Zen. dist.	39	31	N	= Natural cosine		77153		
Cor. decn.	0	28	S.					
Latitude	39	3	North.					

NOTE.—Difference of longitude made after the error on apparent time at ship was determined, is *added* if to the Eastward and *subtracted* if to the Westward. To apparent time at ship *add* West longitude in time, and *subtract* East to get apparent time at Greenwich.

The *sum* of the Log rising of the Hour angle (or Time from noon), the Log cosine of the Latitude by account, and the Log cosine of the Correct declination, will be the Log of a Natural number. This *added* to the Natural sine of the True altitude gives the Natural cosine of the meridian Zenith distance which gets an opposite name to the bearing of the Sun.

LONGITUDE BY CHRONOMETER.

1880—September 22nd, P.M. at ship, latitude 54° 55′ S., observed altitude ⊙ 18° 33′ 15″, height of eye 19 feet. Time by chronometer 22d. 8h. 55m. 15s., which had been found to be 3m. 43s. fast of mean time at Greenwich on 18th July at noon, and 1m. 16s. fast of mean time at Greenwich on 22nd August at noon. Required the longitude:—

	M.	S.
July 18,	3	43 fast.
Aug. 22,	1	16 fast.
13	2	27
22	60	
35	147	(4·2 =
	140	daily loss.
	70	

H.	H.	S.	S.
24	9	4·2	1·6
		9	
	24	37·8	(1·6 =
		24	loss for
9		138	9 hours.
22		144	
31			
4·2			
6 2			
124			
130·2			
1·6			
60)131·8			
2 12			

	D.	H.	M.	S.
Time	22	8	55	15
Fast	—		1	16
Time	22	8	53	59
Acc. rate	+		2	12
M.T.Gh.	22	8	56	11

	°	′	″
Obs. alt.	18	33	15
Dip	—	4	11
	18	29	4
Refr.	—	2	49
	18	26	15
Parl.	+	0	8
	18	26	23
S.-diar.	+	15	59
True alt.	18	42	22

	°	′	″	
Decn.	0	4	1	N.
Decrs.	—	8	40	S.
Cor. decn.	0	4	39	S.
	90			
P. dist.	89	55	21	

	°	′	″
T. alt.	18	42	22
P. dist.	89	55	21
Lat.	54	55	00
Sum.	163	32	43
½ Sum.	81	46	22
Rem.	63	4	00

	M.	S.
Eqn.	7	30·62
Incrs.	+	7·75
Cor. equ.	7	38·37

Cosec.	0·000000	
Secant	0·240508	
Cosine	9·155636	
Sine	9·950138	
Horary angle	9·346282	
	9·346180	s.
	10·2 = 2	

·155957	Diff.	1457	
321		22	
·155636		2914	
		2914	
		320·54	

	D.	H.	M.	S.
A. T. S.	22	3	44	52
Eqn.	—		7	38
M. T. S.	22	3	37	14
M. T. Gh.	22	8	56	11
		5	18	57
	60			
	4)318		57	
Longitude		79	44	15 West.

	″
Var. decn. =	58·46
	8·9
	52614
	46768
60)520·294	
	8 40

	s.
Var. eqn. =	0·871
	8·9
	7839
	6968
	7·7519

	′	″
S.-diar. =	15	59

NOTE.—Write down time by chronometer, then apply error of chronometer on last of two dates, then apply accumulated rate from last of two dates to time of observed altitude.

If Latitude and Declination are contrary names add 90° to get Polar distance and *vice versa*. If Polar distance is above 90° look for Secant of Declination. Apply Equation of time to apparent time at ship as directed on page I of the *Nautical Almanac*, to get mean time at ship. Longitude is East when Greenwich time is less than ship time, and West when greater than ship time.

LONGITUDE BY CHRONOMETER.

1880—March 21st, A.M. at ship, latitude 26° 45′ S., observed altitude ⊙ 35° 3′ 15″, height of eye 22 feet. Time by chronometer 20d. 9h. 20m. 0s. which had been found to be 21m. 59s. fast of mean time at Greenwich, on 11th February, 1880, at noon, and 7m. 24s. fast of mean time at Greenwich, on 3rd December 1879, at noon. Required the longitude :—

	M.	S.
Dec. 3, 1879,	7	24 f.
Feb. 11, 1880,	21	59 f.
	14	35

28 31 11 70

60
70)875(12·5 = 70 daily.
175 gain.
140
350

H.	H.	S.	S.
24	9	12·5	4·7

9
24)112·5(4·7 = 96 gain for 9 hours.
165
168

18 21 39 12·5 195 78 39 487·5 4·7 60)492·2 8 12

Var. decn. = 59·21
8·8
47368
47368
60)521·048
8 41

	S.
Var. eqn.	= 0·755
	8·8
	6040
	6040
	6·6440

″
S.-diar. = 16 5

	D.	H.	M.	S.		°	′	″		M.	S.
Time	20	9	20	0	Decn.	0	6	41 N.	Eqn.	7	27·29
Fast	—		21	59	Incrs.	+ 8	41	N.	Decrs.	—	6·64
Time	20	8	58	1	Cor. decn.	0	15	22 N.	Cor. eqn.	7	20·65
Acc. rate		— 8	12			90					
M.T. Gh.	20	8	49	49	P. dist.	90	15	22			

	°	′	″		°	′	″		
Obs. alt.	35	3	15	T. alt.	35	13	37		
Dip.	—	4	30	P. dist.	90	15	22	Cosec.	0·000004
	34	58	45	Lat.	26	45	00	Secant	0·049159
Refr.	—	1	21	Sum	152	13	59		
	34	57	24	½ Sum	76	6	59	Cosine	9·380122
Parl.	+	0	8	Rem.	40	53	22	Sine	9·815977
	34	57	32					Horary angle	9·245262
S.-diar.	+	16	5						9·245090 s.
True alt.	35	13	37						17·2 = 3

			D.	H.	M.	S.
·380624	Diff.	851	21	0	0	0
502		59		3	18	23
·380122		7659	A.T.S.	20	20	41	37
		4255	Eqn.		+	7	21
		502·09	M.T.S.	20	20	48	58
·815924	Diff.	243	M.T.Gh.	20	8	49	49
53		22			11	59	9
·815977		486			60		
		486		4)719	9		
		53·46	Longitude	179	47	15	East

Note.—The Remainder is got by subtracting the True altitude from the ½ Sum. The Horary angle gives apparent time at ship with P.M. sights, but with A.M. sights it must be subtracted from 24 hours and called the day previous.

Multiply the Diff. by the seconds and always point off two figures from the right, that which remains is subtracted when a Cosine or Cosecant, and added when a Sine or Secant.

DEVIATION BY AN AZIMUTH OF THE SUN.

1880—March 21st, mean time at ship, 8h. 25m. P.M., latitude 24° 55′ S., longitude 98° 45′ W., Sun's bearing by compass, W.S.W., observed altitude ⊙ 27° 33′ 15″, height of eye, 16 feet. Required the true azimuth and error of the compass, and supposing the variation to be 12° 30′ W. Required the deviation of the compass for that position of the ship's head :—

Long. 98° 45′ W.
4
60)395 0
6 35 0

Var. = 59″·16
15
29580
5916
60)887·40
14 47

S.-diar. = 16′ 5″

	D.	H.	M.	S.
M.T.S. March	21	8	25	0
Long. in time	+	6	35	0
M.T.Gh. Mar.	21	15	0	0

	°	′	″
Declination	0	30	22 N.
Increasing	+	14	47 N.
Cor. decn.	0	45	9 N.
	90		
Polar dist.	90	45	9

	°	′	″
Obs. alt.	27	33	15
Dip	−	3	50
	27	29	25
Refr.	−	1	49
	27	27	36
Parl.	+	0	8
	27	27	44
S.-diar.	+	16	5
True alt.	27	43	49

	°	″	
P. dist.	90	45	9
T. alt.	27	43	49 Secant 0·052996
Lat.	24	55	00 Secant 0·042430
Sum	143	23	58
½ Sum	71	41	59 Cosine 9·496919
Rem.	19	3	10 Cosine 9·975539
			2)19·567884
	37	27	= Sine 9·783942
		2	

True azimuth	N.	74	54 W.
Mag. azimuth	N.	112	30 W.
Error		37	36 E.
Variation		12	30 W.
Deviation		50	6 E.

NOTE.—The difference between the ½ Sum and the Polar distance is the Remainder. Name the True azimuth from the south in north latitude, and *vice versa;* towards the east in the morning, and *vice versa.* If one azimuth is north and the other south, subtract the Magnetic from 180°, and change the north or south name *only;* then the difference is the Error, unless one is east and the other west, when they must be added together for the Error, which is east when the True azimuth is on the right, and west when on the left of the Magnetic bearing. The Deviation is the difference between the Variation as laid down on the chart and the Error of the compass in the ship; it is said to be Easterly when the compass is attracted to the *right* of the Variation on the chart, and *vice versa.* In other words—When the Error and Variation have contrary names, add them together, and give the Deviation the same name as the Error. When the Error and Variation have the same name, subtract the one from the other, and if the Variation is less than the Error, give the Deviation the same name as the Error; but if the Variation is greater than the Error, give the Deviation a contrary name to the Error.

DEVIATION BY AN AMPLITUDE OF THE SUN.

1880—June 13th, at 7h. 13m. A.M. apparent time at ship, latitude 30° 0′ S., longitude 168° 45′ E., Sun's magnetic amplitude observed to be East. Required the true amplitude and error of the compass, and supposing the variation to be 12° 25′ E. Required the deviation of the compass for that position of the ship's head :—

		D.	H.	M.	S.		°	′	″	
Long. 168° 45′ E.	A. T. S., June,	12	19	13	0	Declination,	23	12	10	N
4	Long. in time,	—	11	15	0	Increasing,	+	1	11	N.
60)675 0	A. T. Gh., June,	12	7	58	0	Corr. decn.,	23	13	21	N.
11 15 0										
			°	′						
Var. = 8·82	Latitude,		30	0	S.	Secant,	0·062469			
8	Declination,		23	13	N.	Sine,	9·595727			
60)70·56	True amplitude E.,		27	5	N.	Sine,	9·658196			
1 11	Mag. amplitude E.,		0	0	N.					
	Error,		27	5	W.	If the True and Magnetic amplitudes are both North or both South, *subtract* for the Error, but if one is North and the other South, *add* for the Error.				
	Variation,		12	25	E.					
	Deviation,		39	30	W.					

1880—August 15th, at 6h. 36m. P.M. apparent time at ship, latitude 52° 15′ S., longitude 42° 12′ W., Sun's magnetic amplitude observed to be W.N.W. Required the true amplitude and error of the compass, and supposing the variation to be 5° 16′ E. Required the deviation of the compass for that position of the ship's head :—

		D.	H.	M.	S.		°	′	″	
Long. 42° 12′ W.	A. T. S., August	15	6	36	0	Declination,	13	52	3	N.
4	Long. in time,	+	2	48	48	Decreasing,	—	7	24	N.
60)168 48	A. T. Gh., August,	15	9	24	48	Corr. decn.,	13	44	39	N.
2 48 48										
			°	′						
Var. = 47·19	Latitude,		52	15	S.	Secant,	0·213094			
9·4	Declination,		13	45	N.	Sine,	9·376.03			
18876	True amplitude W.,		22	51	N.	Sine,	9·589097			
42471	Mag. amplitude W.,		22	30	N.					
60)443·586	Error,		0	21	E.	If True amplitude is reckoned from the East and Magnetic amplitude from the West, or *vice versa*, add them together and subtract their sum from 180° for the Error.				
7 24	Variation,		5	16	E.					
	Deviation,		4	55	W.					

NOTE.—The True amplitude is reckoned from the East in the morning at the ship, from the West in the afternoon, towards the North if declination is North, towards the South if declination is South. The Error is named by looking from the centre of the compass towards the magnetic amplitude; if the true amplitude is to the *right*, the error is said to be Easterly and conversely.

SUMNER'S METHOD OF FINDING A SHIP'S POSITION.

The method of identifying a ship's position at sea with the intersection of two circles of equal altitude was first brought into prominence by Captain T. H. Sumner, of Boston, Massachusetts, in the year 1843 ; but, owing to the multiplicity of figures required in the calculation, the system never met with the popularity it deserved.

Sumner's method of determining a ship's position involves finding (by means of one observed altitude and two assumed latitudes) two longitudes by chronometer and joining the two positions thus obtained by a line on the chart, then, after allowing sufficient time for a difference in the bearing of the object, of not less than 30°, two other longitudes are found by means of a second observed altitude, and the positions joined by a line as before. The intersection of the two lines of position upon the chart, after projecting the course and distance made good in the interval between the observations, determines the position of the ship at the time of the last observation.

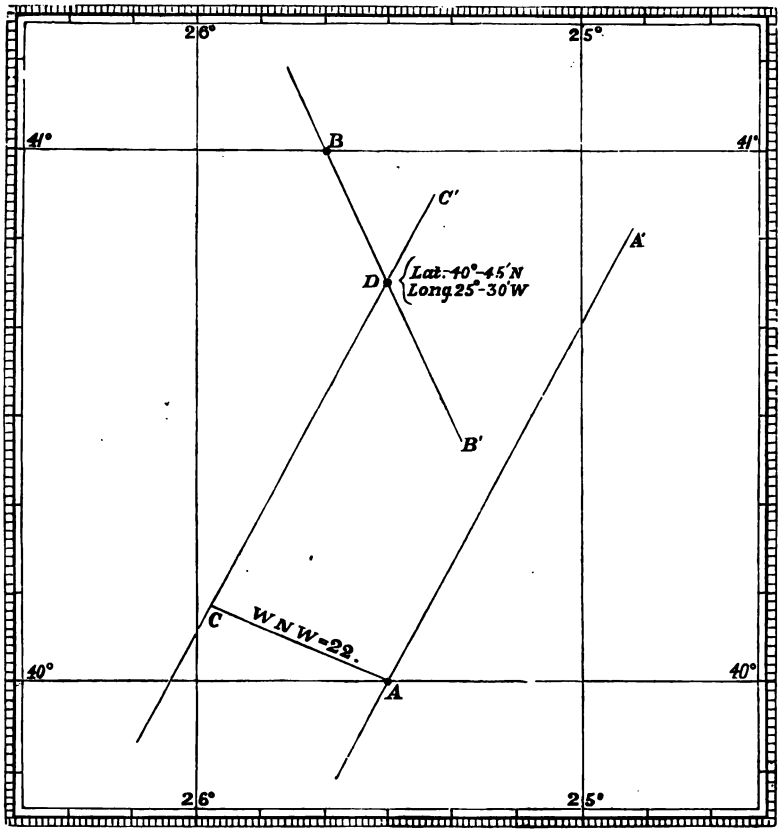
This process can be much simplified by the use of the Azimuth Tables (see opposite page), for as the direction of the line of position is always at right angles to the true bearing of the object, it follows that if the true bearing of the object is known, the line of position will be found at an angle of 90° from it, and the necessity of determining the second position obviated.

The value of Sumner's method for Stellar observations is brought into prominence by Sir William Thomson in his "Tables for Facilitating Sumner's Method at Sea," which dispense entirely with the use of logarithmic sines, tangents, and secants, and include all auxiliary tables ; thus, when making the land at night, and not having seen the sun during the day, if the stars become visible when there is anything of a good horizon, two altitudes can be taken almost simultaneously, and the ship's place, with the consequent bearing of the land, easily ascertained.

First Observation. Apparent Time, 9 h. 32 m. A.M.

Sun's True Altitude.	Sun's Declination.	Assumed Latitude.	Resulting Longitude by Chronometer.	Sun's True Bearing or Azimuth.	Direction of Line of Position.
38° 20′	14° 10′ N.	40° 0′ N.	25° 30′ W.	N. 118° E.	N. 28° E. AA′
		Point A.			
Second Observation. Apparent Time, 2 h. 40 m. P.M.					
36° 50′	14° 10′ N.	41° 0′ N.	25° 40′ W.	N. 116° W.	N. 26° W. BB′
		Point B.			

Run of ship in the interval = W.N.W, 22 miles = AC.
Line of position AA′ projected for run of ship = CC′.
Position of ship at the time of last observation = D.



LONGITUDE BY EQUAL ALTITUDES OF THE SUN.

From five to ten minutes before Noon, observe an altitude of the Sun, and take note of the time by chronometer. When the Sun has crossed the meridian and fallen to the *same altitude*, note the time again.

To the sum of these times divided by 2, apply the error of the chronometer, which will give mean time at Greenwich, corresponding to the mean noon of the ship; then apply the Equation of time as to *mean time* (page II. "Nautical Almanac"), and the result will be *apparent time* or the longitude in time at Noon.

EXAMPLE.

1880—May 10th, latitude by account 2° 30′ N., longitude by account 70° 10′ W., chronometer 3m. 5s. fast of mean time at Greenwich. Required the longitude:—

			H.	M.	S.
Obs. Alt. ☉	A.M. 72° = Time		4	30	20
	P.M. 72° = Time		4	46	10
Sum - - -		2	9	16	30
Half-Sum - -			4	38	15
Chronometer Fast -				— 3	5
Mean time, Greenwich			4	35	10
Equation of Time -				+ 3	46
Apparent Time -			4	38	56
			60		
		4	278	56	0
Longitude - -			69	44	0 W.

NOTE.—Equal altitudes may be observed from about 5 minutes before to 5 minutes after noon, and the mean longitude resulting from 2 or 3 pairs of such observations may be considered quite as reliable as the longitude found by the ordinary sights, provided the Sun's zenith distance is not greater than 5° to 10°; but when the meridian zenith distance amounts to 20°, it would be well to extend the time of taking the sights to 20 minutes before and after noon.

When the Sun's declination is nearly equal to the latitude, the time during which sights may be taken is much extended; and sights before 11h. A.M. or after 1h. P.M. will give reliable results.

In low latitudes (as in the Tropics) observations for time may be taken when the Sun is very near the meridian, for the condition that the Sun should be near the prime vertical may then be satisfied within a few minutes of noon; and in cases when the ship's latitude is exactly equal to the declination (same name), it will be satisfied only when the Sun is on the meridian in the zenith.

PUBLICATIONS MORE OR LESS USEFUL FOR NAVIGATION.

Nautical Almanac for the year.
Admiralty Lights for the year.
Admiralty Tide Tables for the year.
Navigation Tables, Raper or Norie.
Stellar Azimuth Tables, Croudace.
Lunar and Horary Tables, Thomson.
Tables to Facilitate the Practice of Great Circle Sailing, Towson.
Tables for Finding Latitude and Longitude in Cloudy Weather, Johnson.
Tables for Facilitating Sumner's Method at Sea, Sir William Thomson.
Diagrams to Facilitate the Obtaining a Ship's Position by Sumner's method, Burdwood.
Sun's True Bearing, or Azimuth Tables between the parallels of 30° and 60° inclusive, Burdwood.
Sun's True Bearing, or Azimuth Tables between the parallels of 30° N. and 30° S. inclusive, Davis.
Elementary Manual for Deviation of the Compass, Evans.
Admiralty Manual for Deviation of the Compass.
Chart of the Curves of Equal Magnetic Variation.
Admiralty Catalogue of Charts and Sailing Directions.
International Signal Book, with Appendix for the year.
How to find the Stars and their use at Sea, Rosser.
Barometer Diagrams for every Month, Napier.
Diagrams for working the Deviations, Napier.
Seamanship, Sir George S. Nares.
Sailor's Pocket Book, Bedford.

In such cases the longitude may be found as accurately as can be expected, by observations of equal altitudes taken within a few minutes of each other; that is, a few minutes before and a few minutes after noon. In the short interval there is no appreciable change of declination; consequently, no equation of equal altitudes, and the correction for change of latitude may be disregarded. The only work, therefore, is to apply the equation of time, with its proper sign, to 0h. 0m. 0s. or 24h. 0m. 0s., the time of apparent noon, (or apply the equation with the sign *reversed* to the time by chronometer), and to deduce the longitude in the usual way from the Greenwich Mean Time as determined by the chronometer.

DEVELOPMENT OF THE LAW OF STORMS.

DESCRIPTION OF CYCLONES.

Hurricanes, Typhoons, and all circular or revolving storms, are known by the name "Cyclone," which is derived from a Greek word signifying *in a circle, round about, from all sides.*

A Cyclone is an advancing mass of atmosphere sweeping round a central area of *low* barometric pressure, in a direction *contrary* to that of the hands of a watch, or from right to left, in the Northern Hemisphere; in the *reverse* direction in the Southern Hemisphere. In other words, revolving *against* the Sun in both hemispheres.

The central area of *low* pressure, which sometimes covers a space of 20 miles in diameter, has no wind, but a fearful mountainous sea from all directions; the common supposition being that the revolving atmosphere, increasing in speed as it draws in towards the centre, and attaining a frightful velocity, finally rises and fills a void in an upper strata of the atmosphere, probably not more than two or three miles above the sea level.

Cyclones range, in different parts of the globe, from 60 to 600 and even 1000 miles in diameter, while they travel at rates varying from 3 to 30, and sometimes in the West Indies, 40 miles an hour.

TRACKS OF CYCLONES.

In those parts of the Tropics nearest the Equator, cyclones move from eastward to westward, and as they progress, they gradually take a more northerly direction in the Northern Hemisphere, and a more southerly direction in the Southern Hemisphere; then about latitude 20° to 25° North and South respectively, or near the Tropics, they curve more and more rapidly, till, beyond the Tropics, they re-curve back to the eastward again, increasing in circumference as they advance.

DIRECTIONS FOR AVOIDING CYCLONES.

The mean angle between the direction of the wind and the bearing of the centre of *low* pressure is now supposed to be about 112°, or nearly 10 points. Upon this supposition the following table is constructed:—

Northern Hemisphere. Bearing of Centre.	Direction of Wind.	Southern Hemisphere. Bearing of Centre.
E.S.E.	North.	W.S.W.
S.S.E.	N.E.	W.N.W.
S.S.W.	East.	N.N.W.
W.S.W.	S.E.	N.N.E.
W.N.W.	South.	E.N.E.
N.N.W.	S.W.	E.S.E.
N.N.E.	West.	S.S.E.
E.N.E.	N.W.	S.S.W.
E.S.E.	North.	W.S.W.

There is a gradual *fall* of the barometer until the centre of *low* pressure has passed, then a gradual *rise* until the ship is out of the influence of the cyclone.

With your *face* to the wind in the Northern Hemisphere, the barometer will be *lowest* on your *right* hand. With your *face* to the wind in the Southern Hemisphere, the barometer will be *lowest* on your *left* hand. This rule applies to all winds except near the Equator.

In the Northern Hemisphere, the *starboard* tack takes a ship to *high* pressure.

In the Southern Hemisphere, the *port* tack takes a ship to *high* pressure. In other words, a ship should be brought to the wind immediately, and carry all possible sail on the *starboard* tack in the Northern Hemisphere, on the *port* tack in the Southern Hemisphere; unless the ship's track when close hauled would coincide with the

usual track of cyclones in that locality, in which case a ship may sometimes scud with advantage.

RULES FOR LAYING-TO.

The right hand semicircle is on the right of the cyclone's course, looking in the direction in which it is moving, and the left hand semicircle on the left.

When in the *right* hand semicircle, heave-to on the *starboard* tack in both hemispheres. When in the *left* hand semicircle, heave-to on the *port* tack in both hemispheres.

INDICATIONS OF AN APPROACHING CYCLONE.

The sun during the day of a blue appearance.

The setting sun of a fiery red colour.

A bright halo round the moon.

The stars very bright and twinkling.

Lightning shooting up from the horizon.

Scud flying about in different directions.

Red colour of clouds, and all objects tinged with red or bright crimson by day or night.

A dense bank of dark clouds on the horizon, having an altitude of 10°, 15°, or 20°, the upper part being of a deep crimson or red colour, reflecting a red light on all objects.

A peculiar moaning noise in the atmosphere.

A confused and troubled agitation of the sea.

Innumerable turtle floating about in a state of stupor during an unnatural calm.

In the Tropics, the gradual fall of the barometer, after allowing for the regular diurnal oscillations.

In the Arctic regions, a luminous appearance on the horizon, commonly of a red tint.

NOTE. — There is considerable evidence to connect cyclones with electricity, and compasses are often rendered temporarily useless during every burst of the heavy squalls which accompany a cyclone.

REGULATIONS FOR PREVENTING COLLISIONS AT SEA.

Orders in Council, 14th August, 1879, and 24th March, 1880.

Preliminary.

Definitions: "Sailing Ship." "Steam Ship."

Art. 1. In the following rules every steam ship which is under sail and not under steam is to be considered a sailing ship; and every steam ship which is under steam, whether under sail or not, is to be considered a ship under steam.

Lights.

Art. 2. The lights mentioned in the following Articles, numbered 3, 4, 5, 6, 7, 8, 9, 10, and 11, and no others, shall be carried in all weathers, from sunset to sunrise.

Lights for Steam Ships.

Art. 3. A seagoing steam ship when under way shall carry;

(*a.*) On or in front of the *foremast*, at a height above the hull of not less than 20 feet, and if the breadth of the ship exceeds 20 feet then at a height above the hull not less than such breadth, a bright *white* light, so constructed as to show an uniform and unbroken light over an arc of the horizon of 20 points of the compass; so fixed as to throw the light 10 points on each side of the ship, viz., from right ahead to two points abaft the beam on either side; and of such a character as to be visible on a dark night, with a clear atmosphere, at a distance of at least five miles.

(*b.*) On the *starboard* side, a *green* light, so constructed as to show an uniform and unbroken light over an arc of the horizon of 10 points of the compass; so fixed as to throw the light from right ahead to 2 points abaft the

beam on the starboard side; and of such a character as to be visible on a dark night, with a clear atmosphere, at a distance of at least two miles.

(*c.*) On the *port* side, a *red* light, so constructed as to show an uniform and unbroken light over an arc of the horizon of 10 points of the compass; so fixed as to throw the light from right ahead to 2 points abaft the beam on the port side; and of such a character as to be visible on a dark night, with a clear atmosphere, at a distance of at least two miles.

(*d.*) The said *green* and *red* side lights shall be fitted with inboard screens, projecting at least three feet forward from the light, so as to prevent these lights from being seen across the bow.

Lights for Ships under Steam Towing other Ships.

Art. 4. A steam ship, when towing another ship, shall, in addition to her side lights, carry two bright white lights in a vertical line one over the other, not less than three feet apart, so as to distinguish her from other steam ships. Each of these lights shall be of the same construction and character, and shall be carried in the same position as the white light which other steam ships are required to carry.

Day and Night Signals for Ships not under Command.

Art. 5. A ship, whether a steam ship or a sailing ship when employed either in laying or in picking up a telegraph cable, or which from any accident is not under command, shall at night carry in the same position as the white light which steam ships are required to carry, and, if a steam ship, in place of that light, three red lights in globular lanterns, each not less than 10 inches in diameter, in a vertical line one over the other, not less than three feet apart: and shall by day carry in a verti-

cal line one over the other, not less than three feet apart, in front of but not lower than her foremast head, three black balls or shapes, each two feet in diameter.

These shapes and lights are to be taken by approaching ships as signals that the ship using them is not under command, and cannot therefore get out of the way.

The above ships, when not making any way through the water, shall not carry the side lights, but when making way shall carry them.

Lights for Sailing Ships.

Art. 6. A sailing ship under way, or being towed, shall carry the same lights as are provided by Article 3 for a steam ship under way, with the exception of the white light, which she shall never carry.

Exceptional Side Lights for Small Sailing Vessels.

Art. 7. Whenever, as in the case of small vessels during bad weather, the green and red side lights cannot be fixed, these lights shall be kept on deck, on their respective sides of the vessel, ready for use ; and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient time to prevent collision, in such manner as to make them most visible, and so that the green light shall not be seen on the port side nor the red light on the starboard side.

To make the use of these portable lights more certain and easy, the lanterns containing them shall each be painted outside with the colour of the light they respectively contain, and shall be provided with proper screens.

Lights for Ships at Anchor.

Art. 8. A ship, whether a steam ship or a sailing ship, when at anchor, shall carry, where it can best be seen, but at a height not exceeding 20 feet above the

hull, a white light, in a globular lantern of not less than eight inches in diameter, and so constructed as to show a clear, uniform, and unbroken light, visible all round the horizon, at a distance of at least one mile.

Lights for Pilot Vessels.

Art. 9. A pilot vessel, when engaged on her station on pilotage duty, shall not carry the lights required for other vessels, but shall carry a white light at the mast head, visible all round the horizon, and shall also exhibit a flare-up light or flare-up lights at short intervals, which shall never exceed fifteen minutes.

A pilot vessel, when not engaged on her station on pilotage duty, shall carry lights similar to those of other ships.

Lights for Open Fishing Boats and other Open Boats, and for Fishing Vessels.

By the Order in Council of 24th March, 1880, the operation of Article 10 of the new Regulations for preventing Collisions at Sea, sanctioned by the Order in Council of the 14th August 1879, has been suspended until the 1st September 1881, and the following Article (Article 9 of the old Regulations of 1863) remains in force till that date.

Art. 10. Open fishing boats and other open boats shall not be required to carry the side lights required for other vessels; but shall, if they do not carry such lights, carry a lantern having a green slide on the one side and a red slide on the other side; and on the approach of or to other vessels, such lantern shall be exhibited in sufficient time to prevent collision, so that the green light shall not be seen on the port side, nor the red light on the starboard side.

Fishing vessels and open boats when at anchor, or

attached to their nets and stationary, shall exhibit a bright white light.

Fishing vessels and open boats shall, however, not be prevented from using a flare-up in addition, if considered expedient.

Overtaken Ships shall show a Light.

Art. 11. A ship which is being overtaken by another shall show from her stern to such last-mentioned ship a white light or a flare-up light.

Sound Signals in Fog, Mist, or Falling Snow.

Art. 12. A steam ship shall be provided with a steam whistle or other efficient steam sound signal, so placed that the sound may not be intercepted by any obstructions, and with an efficient fog horn to be sounded by a bellows or other mechanical means, and also with an efficient bell. A sailing ship shall be provided with a similar fog horn and bell.

In fog, mist, or falling snow, whether by day or night, the signals described in this Article shall be used as follows; that is to say,

(*a.*) A steam ship under way shall make with her steam whistle, or other steam sound signal, at intervals of not more than two minutes, a prolonged blast.

(*b.*) A sailing ship under way shall make with her fog horn, at intervals of not more than two minutes, when on the starboard tack one blast, when on the port tack two blasts in succession, and when with the wind abaft the beam three blasts in succession.

(*c.*) A steam ship and a sailing ship when not under way shall, at intervals of not more than two minutes, ring the bell.

Speed to be Moderate in Fog, Mist, or Falling Snow.

Art. 13. Every ship, whether a sailing ship or steam ship, shall in a fog, mist, or falling snow, go at a moderate speed.

Steering and Sailing Rules.

Two Sailing Ships.

Art. 14. When two sailing ships are approaching one another, so as to involve risk of collision, one of them shall keep out of the way of the other as follows, viz.:—

(*a.*) A ship which is running free shall keep out of the way of a ship which is close-hauled.

(*b.*) A ship which is close-hauled on the port tack shall keep out of the way of a ship which is close-hauled on the starboard tack.

(*c.*) When both are running free with the wind on different sides, the ship which has the wind on the port side shall keep out of the way of the other.

(*d.*) When both are running free with the wind on the same side, the ship which is to windward shall keep out of the way of the ship which is to leeward.

(*e.*) A ship which has the wind aft shall keep out of the way of the other ship.

Two Ships under Steam Meeting.

Art. 15. If two ships under steam are meeting end on, or nearly end on, so as to involve risk of collision, each shall alter her course to starboard, so that each may pass on the port side of the other.

This article only applies to cases where ships are meeting end on, or nearly end on, in such a manner as to involve risk of collision, and does not apply to two ships

which must, if both keep on their respective courses, pass clear of each other.

The only cases to which it does apply are, when each of the two ships is end on, or nearly end on, to the other; in other words, to cases in which, by day, each ship sees the masts of the other in a line, or nearly in a line, with her own; and by night, to cases in which each ship is in such a position as to see both the side lights of the other.

It does not apply by day, to cases in which a ship sees another ahead crossing her own course; or by night, to cases where the red light of one ship is opposed to the red light of the other, or where the green light of one ship is opposed to the green light of the other, or where a red light without a green light, or a green light without a red light, is seen ahead, or where both green and red lights are seen anywhere but ahead.

Two Ships under Steam Crossing.

Art. 16. If two ships under steam are crossing, so as to involve risk of collision, the ship which has the other on her own starboard side shall keep out of the way of the other.

Sailing Ship and Ship under Steam.

Art. 17. If two ships one of which is a sailing ship, and the other a steam ship, are proceeding in such directions as to involve risk of collision, the steam ship shall keep out of the way of the sailing ship.

Ships under Steam to Slacken Speed.

Art. 18. Every steam ship when approaching another ship, so as to involve risk of collision, shall slacken her speed or stop and reverse, if necessary.

Optional Sound Signals to indicate the Course of Ships under Steam.

Art. 19. In taking any course authorised or required by these Regulations, a steam ship under way may indicate that course to any other ship which she has in sight by the following signals on her steam whistle, viz.:

One short blast to mean "I am directing my course to starboard":

Two short blasts to mean "I am directing my course to port":

Three short blasts to mean "I am going full speed astern."

The use of these signals is optional; but if they are used, the course of the ship must be in accordance with the signal made.

Ships Overtaking other Ships.

Art. 20. Notwithstanding anything contained in any preceding Article, every ship, whether a sailing ship or a steam ship, overtaking any other, shall keep out of the way of the overtaken ship.

Ships under Steam in Narrow Channels.

Art. 21. In narrow channels every steam ship shall, when it is safe and practicable, keep to that side of the fairway or mid-channel which lies on the starboard side of such ship.

Construction of Articles 14, 16, 17, *and* 20.

Art. 22. Where by the above rules one of two ships is to keep out of the way, the other shall keep her course.

Proviso to Save Special Cases.

Art. 23. In obeying and construing these rules, due regard shall be had to all dangers of navigation; and to any special circumstances which may render a departure from the above rules necessary in order to avoid immediate danger.

No Ship, under any Circumstances, to Neglect Proper Precautions.

Art. 24. Nothing in these rules shall exonerate any ship, or the owner, or master, or crew thereof, from the consequences of any neglect to carry lights or signals, or of any neglect to keep a proper look-out, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

Reservation of Rules for Harbours and Inland Navigation.

Art. 25. Nothing in these rules shall interfere with the operation of a special rule, duly made by local authority, relative to the navigation of any harbour, river, or inland navigation.

Special Lights for Squadrons and Convoys.

Art. 26. Nothing in these rules shall interfere with the operation of any special rules made by the Government of any nation, with respect to additional station and signal lights for two or more ships of war or for ships sailing under convoy.

Merchant Shipping Act, 1873.

Duties of Masters in Case of Collision.

In every case of collision between two vessels it shall be the duty of the master or person in charge of each vessel, if and so far as he can do so without danger to his own vessel, crew, and passengers (if any), to stay by the other vessel until he has ascertained that she has no need of further assistance, and to render to the other vessel, her master, crew, and passengers (if any), such assistance as may be practicable, and as may be necessary in order to save them from any danger caused by the collision, and also to give to the master or person in charge of the other vessel the name of his own vessel, and of her port of registry, or of the port or place to which she belongs, and also the names of the ports and places from which and to which she is bound.

If he fails so to do, and no reasonable cause for such failure is shown, the collision shall, in the absence of proof to the contrary, be deemed to have been caused by his wrongful act, neglect, or default.

Every master or person in charge of a British vessel who fails, without reasonable cause, to render such assistance, or give such information as aforesaid, shall be deemed guilty of a misdemeanour, and if he is a certificated officer, an inquiry into his conduct may be held, and his certificate may be cancelled or suspended.

AIDS TO MEMORY, BY THOMAS GRAY

ASSISTANT SECRETARY, MARINE DEPARTMENT, BOARD OF TRADE.

(*Printed by Permission.*)

1. *Two Steam Ships Meeting.*

When all three Lights I see ahead,
I Port my helm, and show my RED.

2. *Two Steam Ships Passing Clear.*

GREEN to GREEN—or, RED to RED—
Perfect safety—Go ahead!

3. *Two Steam Ships Crossing.*

NOTE.—This is the position of greatest danger; there is nothing for it but good look-out, caution, and judgment.

If to my starboard RED appear,
It is my duty to keep clear;
To act as judgment says is proper:
To Port—or Starboard—Back—or, Stop her!

But when upon my Port is seen
A Steamer's Starboard light of GREEN,
There's nought for me to do but see
That GREEN to Port keeps clear of me.

4. *All Ships must keep a good look-out, and Steam Ships must stop and go astern, if necessary.*

Both in safety and in doubt,
I always keep a good look-out;
In danger, with no room to turn,
I Ease her—Stop her—Go astern!

SIGNALS OF DISTRESS.

MERCHANT SHIPPING ACT, 1873.

The Board of Trade give Notice, that on and after the 1st of November 1873, the following signals shall, in accordance with the 18th section of the Merchant Shipping Act, 1873, be deemed to be signals of distress :—

"*In the day-time.*—The following signals numbered 1, 2, and 3, when used or displayed together or separately, shall be deemed to be signals of distress in the day-time, viz. :—

"1. A gun fired at intervals of about a minute.

"2. The International Code signal of distress indicated by N.C.

"3. The distant signal consisting of a square flag, having either above or below it a ball, or anything resembling a ball.

"*At night.*—The following signals numbered 1, 2, and 3, when used or displayed together or separately, shall be deemed to be signals of distress at night, viz. :—

"1. A gun fired at intervals of about a minute.

"2. Flames on the ship (as from a burning tar barrel, oil barrel, &c.)

"3. Rockets or shells of any colour or description fired one at a time at short intervals."

And "Any Master of a vessel who uses or displays, or causes or permits any person under his authority to use or display any of the said signals, except in the case of a vessel being in distress, shall be liable to pay compensation for any labour undertaken, risk incurred, or loss sustained, in consequence of such signal having been supposed to be a signal of distress, and such compensation may, without prejudice to any other remedy, be recovered in the same manner in which salvage is recoverable."

THOMAS GRAY,

Assistant Secretary of the Marine Department of the Board of Trade.

SIGNALS FOR PILOTS.

MERCHANT SHIPPING ACT, 1873.

The Board of Trade give Notice, that on and after the 1st of November 1873, if a vessel require the services of a pilot, the signals to be used and displayed shall, in accordance with the 19th section of the Merchant Shipping Act, 1873, be the following, viz :—

"*In the day-time.*—The following signals numbered 1 and 2, when used or displayed together or separately, shall be deemed to be signals for a pilot in the day-time, viz :—

"1. To be hoisted at the fore, the Jack or other national colour usually worn by merchant ships, having round it a white border, one-fifth of the breadth of the flag.

"2. The International Code pilotage signal indicated by P.T.

"*At night.*—The following signals numbered 1 and 2, when used or displayed together or separately, shall be deemed to be signals for a pilot at night, viz. :—

"1. The pyrotechnic light commonly known as a blue light every fifteen minutes.

"2. A bright white light, flashed or shown at short or frequent intervals just above the bulwarks, for about a minute at a time."

And "Any Master of a vessel who uses or displays, or causes or permits any person under his authority to use or display any of the said signals, for any other purpose than that of summoning a pilot, or uses or causes or permits any person under his authority to use any other signal for a pilot, shall incur a penalty not exceeding twenty pounds."

C. CECIL TREVOR,
Assistant Secretary of the Harbour Department of the Board of Trade.

INSTRUCTIONS FOR USING THE ROCKET LINES FOR SAVING LIFE FROM SHIPWRECK.

If your Vessel is Stranded and a Rocket with a line is fired over it, get hold of the line as soon as you can, and haul it from the shore till you get a tailed Block with an endless fall rove through it; make the tail of the Block fast to the Mast about fifteen feet above the deck. If the Masts are gone, to the highest secure part of your Vessel, then unbend the Rocket Line from the Whip, and signal to the shore by waving a flag or cap in the day, and at night by waving a light.

A Hawser will then be bent to the Whip, and hauled off to your Ship from the shore. Make fast the end of the Hawser 18 inches higher up the mast than the tailed Block, taking care that there are no turns of the Whip round the Hawser. When the Hawser is fast let go the line by which it is bent to the Whip and signal again. The men on shore will then set the Hawser taut, and haul off to you along it, a breeches buoy; let one man immediately get into the buoy, thrusting his legs through the breeches; signal as before and he will be hauled ashore, and the empty buoy returned to the ship again and again till all are landed.

If the Hawser cannot be hauled off, the Sling Buoy will be sent instead, and the persons hauled through the surf to the shore.

Success depends on coolness and attention to the above rules. All Women, Children, Passengers, and helpless persons, should be landed first.

INSTRUCTIONS RESPECTING THE BLUE ENSIGN.

(Naval Reserve Flag.)

British Merchant Ships, commanded by Officers of the Royal Naval Reserve, and fulfilling the following conditions, will be allowed to wear a Blue Ensign :—

CONDITIONS.

1. The Officer Commanding the Ship must be an Officer of the Royal Naval Reserve.

2. At least Ten of the Crew must be Men belonging to the Royal Naval Reserve.

3. Before hoisting the Blue Ensign, the Ship must be provided with an Admiralty Warrant.

NOTE 1.—Ships failing to fulfil the above conditions, unless such failure is caused by death or other circumstances over which the Owners have no control, will no longer be entitled to wear the Blue Ensign.

NOTE 2.—The Captain of one of Her Majesty's Ships meeting a Ship carrying the Blue Ensign may, in order to ascertain that the above conditions are strictly carried out, send on board an Officer, not below the rank of Lieutenant, at any convenient opportunity; but this restriction as to the rank of the Boarding Officer is in no way to limit or otherwise affect the authority or the duties of Naval Officers, either under the Merchant Shipping Acts, or in time of War.

NOTE 3.—Applications for permission to wear the Blue Ensign will be forwarded to the Admiralty from the Lords of the Committee of Privy Council for Trade, who will issue regulations as to the mode of proceeding.

APPENDIX.

Printed by Permission of the Royal National Life-Boat Institution.

ON THE MANAGEMENT OF OPEN BOATS IN HEAVY SURF AND BROKEN WATER.

THE NATIONAL LIFE-BOAT INSTITUTION, some time since, collected information from 128 different places on the coasts of the United Kingdom regarding the system of management of boats in a surf and broken water, pursued by fishermen and other coast boatmen.

It has appeared to the Committee of the Institution that the information obtained in this manner and in other ways may with advantage be published and circulated for the guidance of those who may have insufficient experience in the management of boats under such circumstances.

Rules for the management of boats in a surf and broken water naturally fall under two heads, viz.:—1st. Their management when proceeding from the shore to seaward against the direction of the surf. 2nd. Their management under the opposite circumstances of running for the shore before a broken sea.

Before stating the course to be pursued under each head, we may remark that it is an axiom almost universally acknowledged, that there is, as a general rule, far more danger when running for the shore before a broken sea, than when being propelled against it on going from the land; the danger consisting in the liability of a boat to broach-to and upset, either by running her bow under water, or being thrown on her beam-ends and overturned broadside on.

RULES OF MANAGEMENT.

I. *In Rowing to Seaward.*

As a general rule speed must be given to a boat rowing against a heavy surf. Indeed, under some circumstances, her safety will depend on the utmost possible speed being attained on meeting a sea. For

if the sea be really heavy, and the wind blowing a hard on-shore gale, it can only be by the utmost exertions of the crew that any headway can be made. The great danger then is, that an approaching heavy sea may carry the boat away on its front, and turn it broadside on, or up-end it, either effect being immediately fatal. A boat's only chance in such a case, is to obtain such way as shall enable her to pass, end on, through the crest of the sea, and leave it as soon as possible behind her. Of course if there be a rather heavy surf, but no wind, or the wind off shore, and opposed to the surf, as is often the case, a boat might be propelled so rapidly through it, that her bow would fall more suddenly and heavily after topping the sea, than if her way had been checked; and it may therefore only be when the sea is of such magnitude, and the boat of such a character, that there may be a chance of the former carrying her back before it, that full speed should be given to her.

It may also happen that, by careful management under such circumstances, a boat may be made to avoid the sea, so that each wave may break ahead of her, which may be the only chance of safety in a small boat; but if the shore be flat, and the broken water extend to a great distance from it, this will often be impossible.

The following general rules for rowing to seaward may therefore be relied on:—

1. If sufficient command can be kept over a boat by the skill of those on board her, avoid or "dodge" the sea if possible, so as not to meet it at the moment of its breaking or curling over.

2. Against a head gale and heavy surf, get all possible speed on a boat on the approach of every sea which cannot be avoided.

3. If more speed can be given to a boat than is sufficient to prevent her being carried back by a surf, her way may be checked on its approach, which will give her an easier passage over it.

II. *On Running before a Broken Sea, or Surf, to the Shore.*

The one great danger, when running before a broken sea, is that of *broaching-to.* To that peculiar effect of the sea so frequently destructive of human life, the utmost attention must be directed.

The cause of a boat broaching-to when running before a broken sea or surf is, that her own motion being in the same direction as that of the sea, whether it be given by the force of oars or sails, or by the force of the sea itself, she opposes no resistance to it, but is carried before it. Thus if a boat be running with her bow to the shore, and her stern to the sea, the first effect of a surf or roller, on its overtaking her, is to throw up the stern and as a consequence to depress the bow; if she then has sufficient inertia (which will be proportional to

weight) to allow the sea to pass her, she will in succession pass through the descending, the horizontal, and the ascending positions, as the crest of the wave passes successively her stern, her midships, and her bow, in the reverse order in which the same positions occur to a boat propelled to seaward against a surf. This may be defined as the safe mode of running before a broken sea.

But if a boat, on being overtaken by a heavy surf, has not sufficient inertia to allow it to pass her, the first of the three positions above enumerated alone occurs—her stern is raised high in the air, and the wave carries the boat before it, on its front, or unsafe side, sometimes with frightful velocity, the bow all the time deeply immersed in the hollow of the sea, where the water, stationary or comparatively so, offers a resistance, while the crest of the sea, having the actual motion which causes it to break, forces onward the stern, or after end of the boat. A boat will in this position sometimes, aided by careful oar-steerage, run a considerable distance until the wave has broken and expended itself. But it will often happen, that if the bow be low, it will be driven under water, when the buoyancy being lost forward, whilst the sea presses on the stern, the boat will be thrown end over end; or if the bow be high, or it be protected, as in most life-boats, by a bow air chamber, so that it does not become submerged, that the resistance forward, acting on one bow, will slightly turn the boat's head, and the force of the surf being transferred to the opposite quarter, she will in a moment be turned round broadside by the sea and be thrown by it on her beam-ends, or altogether capsized. It is in this manner that most boats are upset in a surf, especially on flat coasts, and in this way many lives are annually lost amongst merchant seamen when attempting to land, after being compelled to abandon their vessels.

Hence it follows that the management of a boat, when landing through a heavy surf, must as far as possible be assimilated to that when proceeding to seaward against one, at least so far as to stop her progress shoreward at the moment of being overtaken by a heavy sea, and thus enabling it to pass her. There are different ways of effecting this object:—

1. By turning a boat's head to the sea before entering the broken water, and then backing in stern foremost, pulling a few strokes ahead to meet each heavy sea, and then again backing astern. If a sea be really heavy and a boat small, this plan will be generally the safest, as a boat can be kept more under command when the full force of the oars can be used against a heavy surf, than by backing them only.

2. If rowing to shore with the stern to seaward, by backing all the oars on the approach of a heavy sea, and rowing ahead again as soon as it has passed to the bow of the boat, thus rowing in on the back

of the wave; or, as is practised in some life-boats, placing the after-oarsmen, with their faces forward, and making them row back at each sea on its approach.

3. If rowed in bow foremost, by towing astern a pig of ballast or large stone, or a large basket, or a canvas bag termed a "drogue" or drag, made for the purpose, the object of each being to hold the boat's stern back, and prevent her being turned broadside to the sea or broaching-to.

Drogues are in common use by the boatmen on the Norfolk coast; they are conical-shaped bags of about the same form and proportionate length and breadth as a candle-extinguisher, about two feet wide at the mouth, and four and a half feet long. They are towed with the mouth foremost by a stout rope, a small line, termed a tripping line, being fast to the apex or pointed end. When towed with the mouth foremost, they fill with water, and offer a considerable resistance, thereby holding back the stern; by letting go the stouter rope and retaining the smaller line, their position is reversed, when they collapse, and can be readily hauled into the boat.

Drogues are chiefly used in sailing-boats, when they both serve to check a boat's way and to keep her end on to the sea. They are, however, a great source of safety in rowing-boats, and the rowing life-boats of the National Life-boat Institution are now all provided with them.

A boat's sail bent to a yard and towed astern, the yard being attached by a span to a line capable of being veered, hauled, or let go, will act in some measure as a drogue, and will tend much to break the force of the sea immediately astern of the boat.

Heavy weights should be kept out of the extreme ends of a boat; but when rowing before a heavy sea the best trim is deepest by the stern, which prevents the stern being readily thrown on one side by the sea.

A boat should be steered by an oar over the stern, or on one quarter when running before a sea, as the rudder will then at times be useless. If the rudder be shipped, it should be kept amidships on a sea breaking over the stern.

The following general rules may therefore be depended on when running before, or attempting to land, through a heavy surf or broken water:—

1. As far as possible avoid each sea by placing the boat where the sea will break ahead or astern of her.

2. If the sea be very heavy, or if the boat be very small, and especially if she have a square stern, bring her bow round to seaward and back her in, rowing ahead against each heavy surf that cannot be avoided sufficiently to allow it to pass the boat.

3. If it be considered safe to proceed to the shore bow foremost, back the oars against each sea on its approach, so as to stop the boat's way through the water as far as possible, and if there is a drogue, or any other appliance in the boat which may be used as one, tow it astern to aid in keeping the boat end on to the sea, which is the chief object in view.

4. Bring the principal weights in the boat towards the end that is to seaward, but not to the extreme end.

5. If a boat, worked by both sails and oars, be running under sail for the land through a heavy sea, her crew should, under all circumstances, unless the beach be quite steep, take down her masts and sails before entering the broken water, and take her to land under oars alone as above described. If she have sails only, her sails should be much reduced, a half-lowered foresail or other small headsail being sufficient.

III. *Beaching or Landing through a Surf.*

The running before a surf or broken sea, and the beaching or landing of a boat, are two distinct operations: the management of boats as above recommended, has exclusive reference to running before a surf where the shore is so flat that the broken water extends to some distance from the beach. Thus on a very steep beach, the first heavy fall of broken water will be on the beach itself, whilst on some very flat shores there will be broken water as far as the eye can reach, sometimes extending to even four or five miles from the land. The outermost line of broken water, on a flat shore, where the waves break in three and four fathoms water, is the heaviest, and therefore the most dangerous, and when it has been passed through in safety, the danger lessens as the water shoals, until, on nearing the land, its force is spent and its power harmless. As the character of the sea is quite different on steep and flat shores, so is the customary management of boats on landing, different in the two situations.

On the flat shore, whether a boat be run or backed in, she is kept straight before or end on to the sea until she is fairly aground, when each surf takes her further in as it overtakes her, aided by the crew, who will then generally jump out to lighten her, and drag her in by her sides. As above stated, sail will in this case have been previously taken in, and the boat will have been rowed or backed in by oars alone.

On the other hand, on the steep beach it is the general practice, in a boat of any size, to retain speed right on to the beach, and in the act of landing, whether under oars or sail, to turn the boat's bow half round towards the direction from which the surf is running, so that she may

be thrown on her broadside up the beach, where abundance of help is usually at hand to haul her as quickly as possible out of the reach of the sea. In such situations, we believe, it is nowhere the practice to back a boat in stern foremost under oars, but to row in under full speed as above described.

IV. *Boarding a Wreck or a Vessel, under Sail or at Anchor, in a Heavy Sea.*

The circumstances under which life-boats or other boats have to board vessels, whether stranded or at anchor, or under way, are so various that it would be impossible to draw up any general rule for guidance. Nearly everything must depend on the skill, judgment, and presence of mind of the coxswain, or officer in charge of the boat, who will often have those qualities taxed to the utmost, as undoubtedly the operation of boarding a vessel in a heavy sea or surf is frequently one of extreme danger.

It will be scarcely necessary to state that, whenever practicable, a vessel, whether stranded or afloat, should be boarded to leeward, as the principal dangers to be guarded against must be the violent collision of the boat against the vessel; or her swamping or upsetting by the rebound of the sea, or by its irregular direction on coming in contact with the vessel's side; and the greater violence of the sea on the windward side is much more likely to cause such accidents. The danger must, of course, also be still further increased when the vessel is aground, and the sea breaking over her. The chief danger to be apprehended on boarding a stranded vessel on the lee side, if broadside to the sea, is the falling of the masts; or if they have been previously carried away, the damage or destruction of the boat amongst the floating spars and gear alongside. It may therefore, under such circumstances, be often necessary to take a wrecked crew into a life-boat from the bow or stern; otherwise a rowing boat, proceeding from a lee shore to a wreck, by keeping under the vessel's lee, may use her as a breakwater, and thus go off in comparatively smooth water, or be at least shielded from the worst of the sea. This is, accordingly, the usual practice in the rowing life-boats around the United Kingdom. The larger sailing life-boats, chiefly on the Norfolk and Suffolk coasts, which go off to wrecks on outlying shoals, are, however, usually anchored to windward of stranded vessels, and then veered down to 100 or 150 fathoms of cable, until near enough to throw a line on board. The greatest care under these circumstances has, of course, to be taken to prevent actual contact between the boat and the ship; and the crew of the latter have sometimes to jump overboard, and to be hauled to the boat by ropes.

In every case of boarding a wreck or a vessel at sea, it is important that the lines by which a boat is made fast to the vessel should be of sufficient length to allow of her rising and falling freely with the sea; and every rope should be kept in hand ready to cut or slip it in a moment if necessary. On wrecked persons or other passengers being taken into a boat in a seaway, they should be placed on the thwarts in equal numbers on either side, and be made to sit down. All crowding or rushing headlong into the boat should be prevented as far as possible; and the captain of the ship, if a wreck, should be called on to remain on board to preserve order until every other person had left her.

PRACTICAL HINTS FOR THE CONSIDERATION AND GUIDANCE OF MERCHANT-SEAMEN AND OTHERS HAVING CHARGE OR COMMAND OF BOATS.

1. Acquire the habit of sitting down in a boat, and never stand up to perform any work which may be done sitting.

2. Never climb the mast of a boat even in smooth water, to reeve halliards or for any other purpose, but unstep and lower the mast in preference. Many boats have been upset, and very many lives lost, from this cause. The smaller a boat, the more necessary this and the foregoing precaution.

3. All spare gear, such as masts, sails, oars, &c., which are stowed above the thwarts, should be lashed close to the sides of a boat; and any heavy articles on the boat's floor be secured as well as possible amidships, to prevent them all falling to leeward together on a heavy lurch of the sea.

4. On a merchant-vessel getting stranded or otherwise disabled in a heavy sea, or on an open coast where there is a high surf on the beach, the crew should remain by their vessel as long as they can safely do so, in preference to taking to their boats. As a general rule, much more risk is incurred in a boat than in a ship, so long as the latter will hold together. Indeed, in a moderate wind on a lee-shore in open situations, and even in a calm, there is frequently more surf than any ordinary ship's boat can with safety attempt, however well managed she may be.

5. After being compelled to abandon a ship in an ordinary ship's boat, too great precaution cannot be taken before attempting to land. Viewed from seaward, a surf has never so formidable an appearance as when seen from the land; persons in a boat outside the broken water are therefore apt to be deceived by it. They should accordingly, if practicable, proceed along the land outside the surf, until

abreast of a coastguard or life-boat station, or fishing village, whence they might be seen by those on shore, who would then signalize to them where they might safest attempt to land, or warn them to keep off; or who might proceed in a life-boat or fishing boat to their aid, the generality of coast fishing boats being far better able to cope with a surf than a ship's boat, and the coast-boatmen being more skilful in managing boats in a surf than the crews of ships. If in the night, double precaution is necessary, and it will in general be much safer to anchor a boat outside the surf until daylight, than to attempt to land through it in the dark. For this reason an anchor and cable should always be put into a boat before leaving the ship, and also two or three buckets, in addition to the baler or hand-pump, which should always be kept in her, so that she might be quickly relieved of any water she might ship.

6. Boats may ride out a heavy gale in the open sea, in safety, if not in comfort, by lashing their spars, oars, &c., together, and riding to leeward of them, secured by a span. The raft thus formed will break the sea: it may either be anchored or drifting, according to circumstances. If the boat has a sail, the yard should be attached to the spars with the sail loosed. It will break much sea ahead. Also a weight suspended to the clue of the sail will impede drift when requisite. In all cases of riding by spars, a sufficient number of oars should be retained in the boat, to be ready for use in case of parting from the spars.

7. Where a surf breaks at only a short distance from the beach, a boat may be veered and backed through it from another boat anchored outside the surf, when two or more boats are in company; or she may be veered and backed in from her own anchor.

8. Ship's boats should, in addition to their oars, masts, and sails, have the following articles placed in them, if possible, before abandoning a ship at sea.

A baler or hand-pump, and buckets; the plug, and a spare one, both fastened by lanyards; spare thole-pins and grummets, if rowed in that manner; two or three spare oars: a small hatchet; an anchor and cable; a long small line such as a whale-line or deep-sea lead-line and any life-buoys or life-belts which are on board. If in the night or at a distance from the land, a lantern and matches, and if available, blue lights or hand rockets. If beyond sight of land, a compass, and telescope, and of course fresh water and provisions. A log-line and sand-glass, a hand-lead and line, small arms and ammunition (with ball-cartridges and small shot). A red flag and a boat-hook for a flag-staff might often be useful to attract attention.

9. In addition to the above, small empty casks or breakers, tightly bunged and lashed along the sides beneath the thwarts, would partially

convert any boat into a life-boat, by making it impossible for her to founder and by increasing her stability; whilst by leaving less space to be occupied by water if filled by a sea, their use would much expedite the process of pumping or baling out.

10. No ship's boat should either be lowered into or hoisted from the water, without first having a rope from the fore-part of the ship made fast to her bows, by which means she will be much steadier, and will be prevented going adrift if the tackles should be prematurely unhooked or carried away. The rudder should be slung to prevent its being lost if accidentally unshipped.

THE END.

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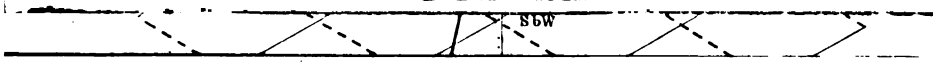
BY ROBERT MACLEHOSE, 153 WEST NILE STREET.

DIAGRAM



DIAGRAM